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CONSTRUCTIONAL STEELWORK:

BEING

NOTES ON THE PRACTICAL ASPECT AND THE PRINCIPLES OF DESIGN:

TOGETHER WITH

AN ACCOUNT OF THE PRESENT METHODS AND TOOLS OF MANUFACTURE.

BY

A. W. FARNSWORTH,

ASSOC. MEM. OF THE INST. OF MECHANICAL ENGINEERS.

With numerous Illustrations.

LONDON:
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PREFACE.

There are in this country some thousands of civil and mechanical engineers, architects, and surveyors who find they have, in increasingly numerous cases, to design and superintend erections involving in some form or other the employment of mild steelwork. A few years ago this material was seldom used except by railway companies, Government departments and a few consulting engineers; but with its adaptation to building and to the ordinary requirements of the smaller engineering enterprises, it has become imperative that every designer should know something about it.

So far as its mere mathematics go, any educated man may easily, in a short time, extract sufficient from any of the many excellent text-books now published to assure himself that his ideas are theoretically beyond reproach, and that he has got a sufficient quantity of metal in the right places to ensure stability. He is, however, badly handicapped by his lack of practical knowledge. He does not know, of himself, the best practical dispositions to make for economy, and all unconsciously he wastes valuable time and money every time he shapes his ideas on paper. This is not his fault, but is due to the lack of opportunity hitherto to correct any notions he may have formed, by reference to some plain account of the essentials and modes of manufacture. Text-books cannot within their limits do more than merely skirt this question, although in reality it is quite as serious and worthy of earnest study as is pure theory.

The present work is an effort to afford to designers generally an indication of what they should seek to embody in their creations; it is hoped that it may be also a handbook for those practically engaged in the trade. As the outcome of a series of articles appearing in *The Engineer* between 1900 and the present time, on various phases of modern steelwork design and practice, some of Part I. of the book will not be altogether new, although it has been entirely rewritten. Part II. has never previously appeared.

The author desires to express his indebtedness to the editor of *The Engineer* for kind counsel and help.

His thanks are also due to the following firms for their courtesy in lending blocks for illustration, or for photographs of special machines:—Messrs Sir Wm. Arrol & Co., Ltd.; Henry Berry & Co., Ltd.; Buck & Hickman, Ltd.; J. Butler & Co.; John Cameron & Co., Ltd.; Campbell & Hunter, Ltd.; Consolidated Pneumatic Tool Co., Ltd.; De Bergue & Co., Ltd.; The Proprietors of *The Engineer*; Messrs Fielding & Platt, Ltd.; Wm. Muir & Co., Ltd.; Peter Pilkington, Ltd.; Rice & Co., Ltd.; Scriven & Co.; Hugh Smith & Co., Ltd.

A. W. FARNSWORTH.

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CONSTRUCTIONAL STEELWORK.

PART I.—PRACTICAL DESIGNING.

CHAPTER I.

IDEAL DESIGNING.

One of the most remarkable developments of the nineteenth century was the gradual growth of engineering enterprises from small to gigantic undertakings, made possible by the discovery and utilisation of new materials. So far as the knowledge of the present generation goes, the span of time known to us as the "Nineteenth Century" stands unparalleled for the records of the achievements of engineering science. The year 1900 looked upon a totally different world to what 1800 saw; and, so far as we know now, it was a world without precedent in the visible proofs of the industry and the intelligence of man. Whether the general happiness and welfare of the community also kept pace is matter for speculation; certain it is, however, that mankind was able to point with somewhat pardonable pride to records and evidences of his thinking and constructive powers that in the former century were not even dreamed of.

The contributory causes were undoubtedly the comparatively peaceful times that were experienced, and the leisure and opportunities that ensued for the cultivation of the peaceful arts. During that period man changed from a combatively warlike to a competitively peaceful individual; he moved the venue of his energies from the stricken field to the counting-house, and his honours were gained in commerce in lieu of in warfare. But the same restless, dissatisfied, grasping spirit which drove him in the previous and preceding centuries to internecine strife and violent war on others, was still, and apparently ever will be, unabated; the direction of its current only was altered, and, guided into other channels, proved its virility by the eagerness with which men strove to eclipse each other's efforts, until when 1900 dawned the earth had been covered by monuments of his prowess which, unlike those of former days, were intended for the benefit and gain of the living rather than as testimonies to the dead only. It could hardly be urged that the human race had suddenly

advanced materially in skill and taken a great stride forward mentally; such developments were more the evidences of greater opportunities and of the new direction given to energies which had formerly been absorbed by the race for temporal powers.

Neither would it be correct to say that in the past smaller things had sufficed because ambition was not so dominant. Rather would it be more true to say that ambition was then limited by possibilities; that the greater possibilities in the nineteenth century enabled ambition to mount; and that, through the prevalence of peace, time had been allowed for investigation in many directions to yield fruit. Man had brought to his hands many strange and hitherto unknown weapons with which to pursue the arts of peace, and with these, employing the energies he formerly lavished so freely elsewhere, he built these monuments to his name. Development was admittedly abnormal, but it was not really strangely so, considering the circumstances of the times.

Looming very largely amongst these new weapons were the various products of iron ore, and with them were created some of the most imposing of the new works. Commencing with cast-iron—which had been known for ages, though not commercially so—that century saw wrought-iron and finally mild steel so highly developed that to-day we have engineering structures of a span, height, and depth formerly deemed impossible. Many other metals besides these are new to that period, but it is to the utilisation and employment of these that the greatest works are due. The mere mention of a Brooklyn Bridge, a Forth Bridge, a Tower Bridge, a *Celtic* or a *Cedric*, or even a typical "skyscraper," conjures up to the imagination a thing of immensity, complexity, and, in a sense, grandeur such as our forefathers never dreamed of An enumeration of the new things that have been created since 1800 dawned would almost be an impossibility—in every direction these metals have been made free use of. All branches of engineering owe to them an immense debt; without them most of our boasted feats would yet have to see the light.

It is with these metals that this work proposes to deal. Not in a historical or dryly technical or theoretical or enumerative sense, but in a purely practical manner. The *present* methods of manufacture, means of manufacture, application, use and abuse—these will be discussed and dissected for the everyday use of the practical man engaged in working with them.

Needless to say, the use of materials of such proved possibilities and such immense probabilities has given birth to a science connected with its application and to a class of men specially skilled and employed therein. Such an important science has its own literature and professors, and he would be a bold man who set out to proclaim new lines of thought or to evolve new theories of action. This work, it may be said, has no such intention. Its object is to call attention to the practical side of constructional engineering as distinct from the theoretical; and to bring to the notice of those engaged wholly or occasionally with the materials of constructional work those

considerations other than theoretical which will help them in the evolution of their designs.

It is a very common fault nowadays to put blind faith in mathematics. The fact is not inherently reprehensible, since it is an outcome of the modern conditions of life, in which the craftsman has ceased to be also the designer; each now goes his own way, and the craftsman too often only cultivates his muscles, whilst the designer drifts more and more from the handicraft to the purely theoretical frame of mind. At the same time the fault is a serious one, for it has given us a class of men whose figures have become their gods, and who are only too prone to believe that the highest aims of life are to be satisfied by a strict adherence to the dictates of theory. On the other hand, the craftsman has grown more and more wedded to the craft, and has come to regard the work itself as the end rather than as the means towards an end. He looks upon the designer with contempt, laughs at his figures, and pins his faith on the old proverb that "an ounce of fact is worth a pound of theory." We have thus two classes, each, by their scorn of and contempt for the methods of the other, gradually driving each other to extremes in their policies.

What could be more disastrous? Neither really knows the other. Both seem to themselves to have the best of grounds for their belief and practices; both have grown bigots in their calling. The one puts scientific education before everything; the other practical apprenticeship. Much acrimony has been shown by both sides in the dissensions that have from time to time taken place, and even personalities have been dragged in and besmirched. Now, no man can say this is engineering, or that such divisions are worthy of supposedly sensible men. As ever, the probabilities are that both are partly right and both are partly wrong; and that a blending of the right in each would produce the ideal. Anyway, it will be freely granted that nothing but good can come of any attempt made by the one to understand the other. It is hoped that the consideration of what follows in this volume may help the theoretical man and the consulting and designing engineer to understand better the position of the practical man and the maker; and perhaps the latter may find help also from its perusal, and be interested in the aims and objects of others, and in the work and tools described.

One of the commonest faults of the designer of any work is to get so interested and wrapped up in his subject as to pursue his work without a proper regard for the £ s. d. involved. A special machine has to be designed for some intricate work, and the draughtsman engaged is both bothered and pleased with his subject—its difficulties perplex him, whilst their solution gives him the keenest gratification. As his mind, engrossed to the exclusion of everything else, grapples with and analyses his problem, he, pleased with an ingenious arrangement of a part, forgets to some extent that the motive for all his work is economy, and designs that part without due inquiry as to whether the arrangement is actually the simplest and most inexpensive that could be adopted. True, the machine, as he turns it out, may make for economy of manufacture; but it is to an extent handicapped by the expense of its own

production from showing the utmost available economy. This is where mathematics and pure theory part ways with practical work. Obviously the right thing to do is to secure the *greatest economy all round.*

Possibly the work in hand is that of a large bridge spanning many hundreds of feet, and involving in its manufacture thousands of tons of mild steelwork. Before a stroke can be put on paper towards the design proper, many reams of figures will have to see the light, and much careful calculation be done. The engineer is aware that he has to pay so many pounds for every ton of material used, and so the obvious economy is to use as little as is barely possible. Proceeding on these lines, he carries his figures to their finest point, and works in his materials, shapes, and sections on the same basis. He would be more than surprised to be told that his design was a very wasteful one, and would at once fly to the conclusion that he had made some errors in his figures. Yet the critic would probably have no such idea. In fact, he might very well be a practically uneducated man who would be puzzled to add together $\frac{3}{4}$ and ·75. What would be meant would be that the engineer had neglected certain axioms known to his critic; axioms and observances that make for inexpensive manufacture, and which, disregarded, put up the price per ton to a much higher figure. He had economised his material and wasted his labour, with the result that he would have to pay much more for his structure than if he had been more liberal with his material and had studied to economise his labour.

The fact that labour costs money hardly seems to be realised in drawing offices other than those attached to a works; and very often is lost sight of even there. The practice of averaging machine tools and mechanical work at a rate per ton, and of buying mild steelwork on a tonnage basis, has contributed, doubtless, very materially to this. It has caused the labour to be lost sight of in the material, and has tended to put a fictitious value on the latter at the expense of the former.

Now, every man engaged in any of the branches of engineering is by his very education willing to freely admit that it is possible to carry good ideas to a point where they lose their value, and become not only worthless, but actively antagonistic to the very points sought. The truth is exemplified so very often in everyone's experience that it is perhaps unnecessary even to mention it. Yet, as engineers, we are constantly and hourly guilty of such practices! We each develop our little idiosyncrasies, our own likes and dislikes, and exhibit in our work leanings towards certain observances; our minds get biased; we like certain points and dislike others, not altogether as the outcome of pure reasoning, but rather in a personal and characteristic way. Our work constantly exhibits these traits, and, so far, it is bad. Habit in designing is fatal to the progressiveness of all work. Instead of dispassionately judging every circumstance in conjunction with all others, we temporarily leave some out of our calculations, knowingly and of set purpose, and try to bring them in later and modify things perhaps a little to suit.

Probably no man is proof against himself, and his nature will out in spite of himself at times. But in the engineering profession, as in the legal, a well-balanced understanding is essential to success, and the engineer must possess the faculty of putting himself outside himself, and of viewing his work and efforts from a disinterested standpoint. He must carefully consider *every* circumstance. He will seldom make the mistake of omitting peremptory points of design and essential factors to successful working; but he is very apt to overlook such apparent trifles as relative costs of designs, not, perhaps, in the larger sense, but in the smaller sense as applied to details. And yet more often than not these are, after all, the controlling factors in costs. The engineer will carefully select a type as being an acknowledged economical one; and he will then clothe that type with so many refinements that he renders it more costly than the supposedly more expensive one that he had rejected. Of course it is more than probable that he would so direct things that in his hands both would manage to retain their comparative costs, and in that case the only test is a comparison with the work of others. But the fact remains that he has not exercised that judicial regard for his work that as a trained man he should have done.

In just this way, then, it too often happens that we ride our hobbies to death. Excessive care in the one instance and carelessness in the others have always been and always will be fatal to the ideal. And yet the ideal is what we are always striving for. Is any improvement announced in any branch of the profession, it is only regarded as a step more towards finality. We know that we shall never arrive there, but it is our constant aim to approximate as closely to it as is humanly possible.

This brings us to the question of "What is, after all, the aim and object of our scheming?" What is it that we are striving for, year in and year out? Why are gigantic and small undertakings being embarked upon every day? Why is the ideal always before us?

The questions are keen ones, and it behoves every engineer to face them and thresh them out. It is of no use shirking them or passing them off. Before we can understand our profession we must understand its root principles and frankly admit them, or the world will never know us as benefactors to our race, notwithstanding the immensity of our projects or accomplishments.

CHAPTER II.

THE GOVERNING FACTOR—ECONOMY.

THERE is a vast deal of talk nowadays of the "higher aims" of the professions, of the "cult of the beautiful," and of "high art." Possibly they who are so glib this way know what they are talking about—it is, at all events, only charitable to suppose so. The pity of it is that they do not render themselves more intelligible to the common herd, and really make clear what they mean. Certain it is that no two people ever agree as to what "high art" is; their time seems chiefly taken up with arguing what it is not.

As engineers we are constantly besought to bring our creations into line with something vaguely denominated "beauty." "Give us beautiful structures" is the cry, and we are hysterically told that we are covering the land with uglinesses. Perhaps so; indeed, it very often is so. But, after all, what is beauty? What is it makes a thing beautiful in our eyes?

Is it not most often a conformability to that which we have often seen before, and that our eyes are accustomed to expect? An æsthetic discussion on "The World Beautiful" is beside the present mark, and it is not desired to debate all the various subtleties of the word. Leaving these alone, then, is not "beauty" a thing of education, a grasping of the constructor's ideas, and an outcome of centuries of human discernment and observation? In a word, is it not entirely a matter of personal standpoint?

If that be so, is there not good reason for everyone's interpretation to differ; would it not be altogether exceptional if we all united in deeming the same things beautiful; and would it not be a very tame world indeed if we did?

True, we have the "canons of art" to guide us all, and as sheet-anchors they must be of value, or so much use would not be made of them. But, indeed, they in their turn are still but the human estimate of beauty's laws, and are but the expressions of ages of individual opinions coalesced into the semblance of a whole. The "cult of the beautiful," considered impersonally, is more amusing than irritating, since its standard is entirely arbitrary and founded on precedent.

To what has the cry led our profession? To rosettes and stars and ogee sections, to elaborate piercings and geometrical patterns! Tosuch a pass have we allowed ourselves to be dragged in the desire to conform to "public sentiment!"

Yet the cry for beauty is not altogether responsible for these outrages on good taste. It certainly prompted them, but would as quickly disown their parentage. The fault rather lies in the engineer who was content to pander to a taste that he failed to gauge, and to attempt a beauty of detail when he should have studied a beauty of form. Beauty is not a thing of patches, or holes, or curves only, but, according to our "canons," of breadth of effect and disposition of form.

Suppose that in the beginning of all things Adam had a Whipple-Murphy truss bridge of three hundred feet span in the Garden of Eden; what would now be our ideas of beauty concerning railway bridges? And suppose that the terminus of the line that he daily used backwards and forwards from his sleeping to his working places was modelled on the lines of St. Pancras; how many should we find condemning the latter to-day? Is there not something in the plea that our sense of beauty does not alter with our opportunities?

Let it be understood that this is not a plea for a new standard of beauty; we have already too many of these. The "cult of the railway bridge" would be rather too far-fetched a notion for even the most enthusiastic engineer. But if there is any truth whatever in what has been said, is it not to be found in the thought that beauty, being altogether a thing of the imagination and the work of time, is not to be arbitrarily applied or withheld from anything until time has shaped a verdict? Certain stone bridges have been very generally described as "beautiful," and have been pointed to as embodiments of what bridges should be. Why?—they are stone, and the world has worked with stone for untold ages! Yes; but it is the *arrangement* of the stone, we are told. Very well; iron or steel is new—we do not know yet how to arrange it, in order to use it properly. It is a significant fact that the stone structures which are most generally admired are the best examples of the highest scientific skill, and those in which the economy of the materials has been brought to the highest pitch.

Stone to the stone-lovers. When engineering skill knows how to take the fullest engineering advantage of mild steel, or any other metal, then will dawn the day of beauty for metal structures. Nature herself wastes nothing. Our standard of beauty is supposedly copied from nature. "High art" seeks to improve on nature. The engineer will succeed in finding nature's beauty just so far as he is successful in copying her example in economising his materials.

The first lesson, then, for the engineer is "economy," even from the beauty standpoint. We are to seek to improve our applications of science, and to get right lines scientifically in our structures, by striving to get ever closer to nature's own examples.

So much for the beautiful in our schemes. But, setting this aside for the present, let us ask, "Why did we ever begin engineering?" In the first instance, the science owed its birth probably to ambition or avarice, quickly giving place to the necessity of earning daily bread. When the first tree was designedly felled so that as it lay it should bridge a chasm or watercourse, utility was the power behind the axe; when the first dam was built across a

stream so as to back up the waters, utility was the strength that fashioned it and when the first boat was rudely hollowed from the tree trunk, utility was the doggedness that scraped it. So it was in the beginning; so it has been down the ages; so it is to-day. Work is for a purpose—a set, hard, uncompromising purpose of utility, of the need for gaining a livelihood. No matter what the subject in hand may be, the engineer is not set to work except for a purpose, and that purpose the greatest possible utility which can be devised.

To what does this lead us, then? Is it not to the fact that utility also spells economy? For, when the first tree was felled, unless the time spent in the felling was worth spending in view of the gain to be got when the felling was over, would the felling ever have been commenced? It is self-evident that the shorter the time occupied the greater the resultant comparative gain. A larger tree than was necessary for the purpose in hand would never be selected, nor would the one with the largest and most beautiful branches, unless these were also part of the utility scheme. The same with the dam and with the boat. The nearest materials to hand would be used for both, with a due regard to the economising of labour on each.

It may be urged that the savage sought to take some of the crudity off his boat by carving and fashioning as his tools allowed. Very likely so; that is but human nature. But he would not do this until he had time he did not otherwise know how to employ. When the purpose was hot upon him for which he must have a boat, he did not dream of ornamentation, but had a single eye only to the most rapid accomplishment of his purpose. The ornamentation was born of more leisured moments. All honour to the spirit that prompted it and to the labour that shaped it; but he did not devise his finery until he was conscious he could afford the cost.

So many critics forget or ignore this. A gaunt, unsightly structure, seen against the skyline and situated amidst nature's beautiful rendering of her own art, provokes from them much wrath and indignation and many scathing phrases and denunciations. The structure is certainly out of all harmony with its surroundings; it is admittedly a blot on the landscape, and it jars on the otherwise peaceful repose of the place. But the railway company who placed it there were not landscape gardeners, nor were their shareholders members of a society for preserving intact at all costs the virginal beauty of nature. The passengers who by their custom retain the bridge in this spot, will they quarrel with the means of taking them to their destination, or of showing them such lovely country? Would they wish to pay higher fares because they knew that by such sacrifices they had contributed to the erection of a bridge more in harmony with the place?

Human nature is essentially selfish. Let the critics offer to provide a suitable bridge themselves. The railway company will not object. It is only when matters touch home that it is realised that, however ugly man's work may be, in the vast majority of cases the reason is a very personal one. The earning of the bread of the multitude is not an abstractly beautiful affair.

Right down the ages, from their very birth, engineering and the engineering instinct have been based on pure utility. The service of mankind has been their guiding star, and the promotion of his closest interests their great objective. Engineering is here meant in the broad sense; everything constructive belongs to this category, and the sense of fashioning, for whatever purpose, is evidence of the engineering instinct. If man had never "wanted," then he would never have engineered; and it is evident that the most successful engineering is that which gets at and satisfies the wants in the quickest and best ways.

All this spells only one thing—economy. Economy of time and of labour. The most economical method of meeting any want must be the best method. The bare want properly supplied at the least possible expenditure is the highest art the engineer is capable of; for it is but nature's own law that energy should be conserved. The strictest and most rigid regard to the laws of economy is the only way in which utility can be successfully interpreted.

By this is not meant that the engineer's chief duty is to strive after unsightliness and ugliness. Far indeed from it. What is meant is that it is his chiefest duty to seek that disposition of his forces that nature herself, were she doing the work, would select. For nature teaches us that in the greatest economy lies the greatest real beauty. What is there on this earth that can be rightly termed "superfluous?" The "economy of nature" is a byword with all of us.

At the same time nature has not scrupled to arrange her economy in the most attractive of forms where she could. Are there not "nature spots" in this world which, owing nothing to man, yet represent to him all that he holds "beautiful"? Places there are without number where nature has seemed to set herself out to the most extravagant advantage; where she has apparently neglected nothing in her scheme of perfection, and where the balance of the parts and the beauty of the detail leave nothing to be desired. On the other hand, are there not to be found localities where everything seems to unite in being as surlily forbidding as others are desirable?—where everything visible appears to frown on man and to evidence to him his own insignificance? Yet none of these places either has or is without anything contributing to the greatest natural economy. We know enough of the laws of this life to convince us that every blade of grass has its place and every stone its objective.

We do not, however, know enough to be able to fashion our own creations on this magnificently planned scale. We do but grope in the dark and strive to imitate as best we may. Our own knowledge and researches have only attained so high, and it is quite possible that we are continually and always running exactly counter to what would be the best. Who knows? We may but always do our best; the rest we have got to leave.

But let "high art" and the "cult of the beautiful" be dropped. They have no real place in nature, though they profess so insistently to be its very seed. Let us rather turn directly to nature and take her first most obvious

laws, "utility" and "economy," and apply them as rigidly as the light within directs us to the work we may have in hand. By unceasing dint of continued applications only can we hope to attain anywhere near to the standard so freely open to us all. Remembering always that as nature can be kind and gentle, fair and attractive, so can also some of our works with like economy be so; and as she can also be the opposite, so must we in turn be at times.

Economy to-day—by the mere force of circumstances—is spelt £ s. d. All time is money, and whether we like it or not we have to bow to the little fat god. Money is the arbiter of everything useful, of everything ornamental. It is safe to say that no project upon which our engineers engage would ever be embarked upon if it were not a question of making more money, or of retaining that which is already possessed. Utility necessitates economy, and economy, the "governing factor" in carrying out engineering works, is entirely regulated by and based upon a monetary standard.

It is not perhaps a nice thing to say; it all sounds very sordid, and the æsthetic amongst us revolt at the idea. But facts are facts, and the engineer must be essentially a man of facts. Who will instance any engineering scheme of to-day not dictated by the exigencies in some way or other of the yellow metal? Occasionally a philanthropist may be found who will embark on a scheme; but why? For the benefit of others. What sort of benefit? Monetary in the end; even though it be a convalescent home it will but have as its purpose the object of curing so that fresh efforts may be put forth in the paramount direction. Brushing aside all sentiment, the one uncontrovertible fact of modern-day life remains, that the first efforts of mankind must be after money.

Wherefore, then, comes the first law of engineering—"The carrying out of every project in the truest economical manner."

"Economy" is meant in the best nature-sense—*The most economical method for the work in hand.*

All this may to some seem rather futile, and perhaps even unnecessary. That it should be so is freely admitted. But every engineer worth his salt has to admit that it is the principle most often lost sight of in everyday designing; and not only that, but most frequently wilfully put behind and carefully kept from troubling. It is to many men a most irritating thing to feel that their abilities are hampered by the dictates of finance. They are naturally ambitious, craving to climb upwards and to show the world the extent of their attainments. They want every job to be a "monument" to their skill and knowledge; they want to justify their success. We all fall victims to the feeling at one time or another, and wish to put on record tangible evidences of what we are capable of. But the feeling is essentially a false one, and one to be sternly combated. Its usual outcome is showiness and an attempt at the imposing, and these of themselves are quite sufficient to prove its falsity. It should be our highest aim to be true to our calling and always to engineer "economically the best for the work in hand." Personal feelings and ambitions have no right to sway our judgment one iota,

or to make us deviate in the slightest way from the "economically best" we are capable of.

Obviously, the "economically best" for any work cannot be arrived at without a full consideration of all the circumstances of the particular case. No two jobs can ever be exactly economically alike, since it is rare indeed that any two sets of conditions will absolutely agree. Every separate case must be independently considered entirely on its own merits and treated accordingly. Take the case of a railway bridge in a new country; say for Central Africa. Money is being ventured at enormous risks; the one and sole object of the line is the strictest utility; it is imperative that the costs be kept down to the lowest possible figure; and that the prospective dividends be the highest that is possible. To what does such a requirement point? To the plainest of plain structures, with not an ounce of superfluous metal, so that cost may be at a minimum. To the rigorous pruning of all requirements not absolutely essential, and the most careful husbanding of all resources. The man who, faced by such requirements, spends one penny above the minimum is morally guilty of theft. He has to spend other people's money in order to gain a definite end for them; whatever he spends more than he need to attain that end is just as much thieving as though it were put straight into his own pocket. Every stroke of the hammer, every turn of the drill, every rasp of the file that he causes to be put on that work in excess of actually needed requirements is just so much waste, and in just so much is he culpable.

Take, on the other hand, the case of a public memorial—a monument perhaps to honour the dead. What is now the "economically best"? Is it not the striving to set before humanity a tribute which, by its fitness and beauty, shall unceasingly remind them of the spirit of its inception? Is it not to be found in giving the best value for the money-limit allowable in time, material, workmanship, and brains? In giving to posterity the utmost that the present is capable of, and seeking to elevate and uplift whilst perhaps material aid is also given? This project is on a different plane; its prime object is to honour; to set high above common things one which shall by its form or beauty compel attention, and so remind the onlooker of the debt posterity owes to a distinguished man. Equally must it be seen, however, that no waste is here; nothing superfluous must be allowed either in or out of sight, but the work put in the right place, and the whole made as perfect as our means and our limitations will allow. Only in that way will the completed work conform to "the most economical method for the work in hand."

Between these two extremes ranges a whole multitude of other possibilities with other conditions. Each case must be separately analysed and treated entirely on its own merits. Above everything the personal factor must be kept out of our deliberations. Nothing is or can be so ruinous to true work as the ever-recurring wish to "stamp our individuality." It is the *work* we are doing, and are paid to do; and a little less personality and a great deal

more honest, self-effacing effort would in the end repay us a thousandfold, even if the mere moral aspect of the question be left out of account.

Many engineers sin this way wittingly; many more, conscious, perhaps, that they have no individuality to stamp, or that the attempt would only end in disaster, violate the "economically best" unwittingly. As was said in the previous chapter, a mere knowledge of theory, or a mere knowledge of practice, is not sufficient to ensure the ideal. Most designers, perhaps, are more familiar with the former than the latter. Certainly it is so in the constructional steelwork branch of our profession.

Is it not, then, imperative that the designer, if he would do the ethically right, should study the mundane and commonplace as represented by the practical? If to money is due our projects, then the laws of money and money's value *must* be assimilated and understood.

CHAPTER III.

THE DUTY OF THE DESIGNER.

THE average estimate by the average designer—whether he be engineer, architect, or belong to any other profession—of his duty towards his principals is that he shall see that his design conforms to the convenience and general wishes of his client, and that he shall safeguard the latter's interests from the rapacity of the contractors employed. Beyond this few professional men go. Work is not always so congenial in itself that they feel they need do more than satisfy their consciences in their undertakings. In fact, the man who really goes so far as to honestly carry out the above generally feels that he is immensely better than his fellows, and that he is continually robbing himself of perquisites which he might enjoy, if only his conscience were less exacting.

Yet this is, after all, a very low view to take of the obligations of the consultant. For the time being he becomes a trustee for others. He not only advises, but he generally also directs the expenditure of other people's monies. He stands to them in the place of themselves, and is trusted to do what they themselves would do with their own had they only the requisite knowledge. He is not exactly a man giving advice to other men sharing the same degree of knowledge. He is an expert, helping and advising, from the storehouse of his special experience, the ignorance of others. In the very nature of things he must be trusted, and often most implicitly.

It is when thinking of these trusts that he most often calls himself a type of rectitude and honour. He has never yet neglected his client's interests to the structural detriment of the work in hand; he has never condoned or passed over bad work, or accepted presents from a contractor, but has always rigidly kept himself aloof from such contaminations. Yet, from the point of view of the last chapter, his morality may in reality be of a very low order! So far as the work that can be seen goes, no man may question his integrity, for no one besides himself knows his instructions, and there is nothing venal in the execution of the work to cavil at. But the test point of it all is far removed from the standard he has set up. Until now he has but followed professional etiquette and pride, even as the ordinary individual follows and obeys the common laws of the land; and just as it is possible to obey the

letter of the law and yet violate its teachings, so has he ignored the spirit of his calling whilst conforming to its precepts.

The duty of the designer goes very much further than the observance of common morality in his profession. Unless he conscientiously uses his knowledge to the best of his ability, to the same ends which his client would were *he* capable, he is falling short of his obvious duties. It is a common saying with a professional man that he spends his client's money as though it were his own. Does he? Yes, so far as seeing that good work is put in the various erections and that money is only paid for work done. But that is not the end of the matter. In order to spend the money as though it were one's own, or, rather, in order to spend it as the client himself would, which is the truer standard, it is necessary to get right down to the motives dictating the spending of the money, and to act with them always in view.

If work is to be done to gratify an ambition, a taste, or a love of display, then, bearing this in mind, the object may be met in the same spirit, and ideas only curbed by the knowledge of the maximum allowable money-limit. If, to take another case, accommodation of a certain character and size at a certain price be desired, then the duty will be to get the utmost value for every penny spent. Whilst to take the case of a commercial undertaking which has to pay dividends, the duty alters at once to that of devising the *necessary* features at the *minimum cost*. This latter case covers the greater part of the available work of the world. There is comparatively little money for the first two—it is the last which oils the wheels of mankind and provides livelihoods for us all.

It is essential that this truth be grasped. Buyers get keener year by year, and competition ever gets more strenuous. Money must earn money, or the increasing wants of the world will never be met. It is the professional class which has been the slowest to understand this, and to recognise that the days of dignified commerce are over. With the advent of international trade rivalry has come the deathblow to unquestioned national supremacy, and the hustle and bustle of modern-day trading has little in common with the methods of fifty years ago. There is small need to dilate on this aspect of the question. It is now generally accepted that, as a nation, we must alter many of our ways if we are to live. It is high time that the professional man also took this to heart.

In order to get the best and largest returns for capital, the sum invested must be absolutely the lowest possible for the scheme in hand. Every pound, every penny beyond the irreducible minimum that is being employed is only so much dead-weight, so much handicap to the expected success. Even as the obvious end of every commercial undertaking is dividends, so is it patent that the less the capital the higher the dividends to be distributed will be. No illustration is needed to prove this—every child knows so much. Yet it puzzles the wisest men to determine what the irreducible minimum actually is or will be for any given case;—what is the least which may be spent upon

land, plant, buildings, equipment, and what is the least sum that dare be adventured for working capital.

Of course it does not always follow in a commercial undertaking that the cheapest *known* work is the right work to adopt. Far from it. Some undertakings never would prosper unless it was apparent that money had been lavished upon them with a free hand, perhaps with even a total disregard of economy. They depend for their very success on obvious luxuries of design and execution, and without them they would not even excite notice. All this is very true; but in their case the money is invested or expended with a set object, and its proper and proportionate outlay will result in the desired direction. What has to be done in these instances is to see that outlay is made on the effective points; that these are brought out and built up in the most striking manner, and that their characteristics are not in any way sacrificed because of unnecessary expenditure in other directions. Everything depends on the nature of the undertaking and what its necessary features are. It would be of small use erecting a large hotel in a prominent position and whitewashing its interior throughout; that would but serve to defeat the object for which the place was built. The hotel will be popular and make money just as its features appeal to the eye; and this must be the first precept in such a case. So that the utmost advantage may be made of the fact, economy must be rigidly observed in that which is not seen; and whilst all the demands of science must be met, they must not be exceeded.

In the same way, if a beautiful appearance is not of prime importance, if, say, the project is that of a huge goods warehouse, what useful object would there be served by anything but whitewash on the walls? Of what use would be fine plaster decoration and ornamental panelling? Not that there would be found men so lacking in common sense as to propose these decorations, but for "plaster" substitute the best-faced bricks, and for "ornamental panelling" oak timbering, and then say how many architects could resist the temptation. On such a scheme there should not be spent one penny more than the minimum necessary to secure the requisite strength and the desired space. It is a commercial undertaking, and knows no laws except those of dividends on outlay.

Broadly, then, the duty of the designer lies in understanding and applying scientifically monetary knowledge. It is not sufficient that he should be artistic—he must be pre-eminently so, to successfully manage some work; it is not sufficient that he be scientific—he must be this for all work; but he must combine with his artistic and scientific senses a thorough understanding of the laws of supply and demand, and must ruthlessly apply it to his every undertaking.

As with the general practitioner, so must it be with the steelwork specialist. He may have every formula ever written at his finger-ends, he may be a mathematician of the first water, he may be a genius in theoretical knowledge; yet, if he lacks the one thing, his designs will never be of the first order, and the thoroughly practical man who can never remember a formula will easily surpass him in the worth of his achievements.

There is, however, a difference between the design of steelwork and that of ordinary undertakings. Steelwork, unlike many other materials, is seldom capable of much artistic treatment. Exceptions there are to every rule; but, generally speaking, steelwork, as previously noticed, is strictly utilitarian in character. It is engineering and not architecture, and should always be treated as such. The chief duty of the engineer will invariably be to produce his designs at the lowest possible cost, and for this purpose he must be prepared to consult details of manufacture to a very large extent. The economy at which he has to aim will not consist in using up the smallest possible weight of materials, but will be measured by the comparative total cost of his work. A given design weighing 100 tons may cost much less than another of 90 tons' weight, and yet both shall be capable of the desired work. It is possible to go further and say that the same design as turned out by one man shall, when overhauled by another, vary a considerable percentage in cost. It is not knowledge of theory that altogether rules the economical design; neither is it practical knowledge, but the judicious combination of the two.

It is a very general idea that the broad choice of design is the chief factor in costs. One man will contend that for a given situation a Linville girder is preferable; another will argue that a common lattice would be better. There will be right on both sides. It is possible to make the Linville cost double what the lattice would, and *vice versâ*. The Linville may be designed with all the refinements known to science, and may have the last ounce of metal cut out of it; it will most probably be for this reason that it is the most expensive girder.

By this is not meant that the principles of design are untrustworthy. Far from it. It is merely their application that is at fault. There are certain well-understood principles which point to the choice of, say, a suspension bridge for a certain spot in preference to one of a rigid type. But it all depends on the designer whether the suspension type is, after all, the cheaper. Without wasting an ounce of material he may turn out a bridge which is far more costly than the rigid type would be if designed by another man.

Too little attention has in the past been given to these points. Men have been content to accept the dicta of others without troubling to investigate them for themselves. Office life and office duties have shut up the engineer in a world of his own, and he has pursued his way without hearing much of the other world with which he only occasionally has come in contact. Methods of manufacture have radically changed within even the last ten years, and the man who to-day bases his designs on his knowledge of workshop conditions of a decade ago is woefully out of the race. In order to produce the best design for any purpose, the methods by which it is to be made must be known and understood. Both men and machines have their limitations, and it is the plain duty of the engineer, the architect, or the designer of any work to bring to his work, not only professional skill and resource, but the wisdom of the money-bags and a personal knowledge of everyday workable conditions.

CHAPTER IV.

TESTS AND ANALYSES.

WITH the actual manufacture of steel, *i.e.*, the production of the material itself, the designer and manufacturer have nothing to do. The process employed is solely the concern of the mills, and criticisms and strictures on methods of production are out of place in any but works on metallurgy. The engineer is concerned mainly with the price he can buy at and the quality of the material bought. Some years ago the question of the process to be used was a very bitter one, and without doubt certain makes or brands of mild steel were superior to others. It thus became the fashion for engineers to specify the material by the trade term applied in its manufacture, and unfortunately the custom has not yet quite died out.

At the time when process counted for much, the metal was very young in the market, and neither its properties nor characteristics were understood. The time which has since lapsed has given us very valuable experience and data on which to work, and recognised tests have been developed which leave very little loophole for doubts on the score of quality. At the present time it may safely be said that, so long as certain mechanical tests are complied with, material of any make or process may be unhesitatingly accepted. There is really nothing at all to choose between the various British brands in the market except the name.

Practically speaking, the British mild-steel industry has adopted three separate methods of production. They are known by various terms in different parts of the country, but may be summarised as being (1) the basic; (2) the Siemens open hearth; and (3) the Siemens-Martin open hearth acid processes. For a long time the third process was preferred by engineers, as its product was the most reliable; but there is not now nearly so much of it made, as severe competition has compelled the use of cheaper ores, and further investigations have perfected methods of using them. The two first-named processes practically monopolise the British trade, with perhaps a percentage in favour of the second, which, through recent discoveries, has not yet taken unto itself a definite name; in some parts it is known as the "open hearth basic." Through the acid process being dependent on foreign expensive ores it is dying a natural death, and in the near future will probably be seldom adopted, except for special purposes.

These different processes have been named solely with a view to emphasising the fact that their several products are practically undistinguishable. It would be interesting to discuss them in detail and to go into their differences of manufacture, but no good would be done to the present purpose, and for such information the reader is referred to the various treatises published upon them. That which concerns the constructive engineer is that he shall have to his hand material fulfilling certain standards of excellence and reliability; and so long as he can procure this in the market, it matters nothing to him whether the ores from which it is made are of low or high grade, or even whether an ore is used at all. This is solely the business of the metallurgist. Of necessity, the tests to be imposed must be such as have been proved by usage, and such as will unfailingly demonstrate the points they have been designed to cover. So long as this is ensured and the well-understood mild steel of to-day is to be employed, it is puerile to impose limits or conditions on manufacture.

Now comes the consideration, What tests should be taken as a standard? Are they to be purely mechanical, purely chemical, or a mixture of both?

In order to properly appreciate arguments on such a question, it should be premised that whatever results are arrived at they must be in accordance with recognised commercial possibilities. It may frankly be admitted that almost any degree of strength and ductility can be achieved by variations of manufacture and juggling of quantities. The steelmaker can from the same hearth produce metals varying astonishingly in their properties, and is able for a price to satisfy any requirement within the bounds of reason. This being granted, it does not need much perspicuity to see that since the engineer must have to his hand a *uniform* product before everything else—one which he can rely on not to fail under a certain figure, and to behave consistently at all times — the steelmaker must make dispositions so as to ensure the necessary uniformity, and to eliminate all chances of a variation of product. It will be also evident that whilst any requirement may be met as stated, yet that the costs of the samples made will not be alike, and that there will be a cheapest and a dearest product, with a whole range of costs in between, according to the scarcities of the ores and the care to be observed in handling them. On the other hand, there will be a cheapest and a dearest steel evolved, considered in the light of their mechanical attainments or physical properties. A steel failing at a unit stress of 30 tons and costing £6 per ton must be compared with a steel failing at 40 tons and costing perhaps £9 per ton; and all the various other properties must be considered in the same way. The ultimate decision rests with the engineer who has to use the material, and naturally he chooses that grade which fulfils his ideals best and gives him the cheapest steel for its properties. The grade chosen, the steelmaker can then lay himself out to produce it in unlimited quantities to maintain the level selected.

This is, briefly, what has taken place in the past ten to fifteen years. A

couple of decades ago wrought-iron was the material in common use, and its production had reached such a pitch that it could be relied upon to consistently show certain results. Then came the gradual innovation of mild steel, and makers and users were again groping in the dark; for a long time it was freely prophesied that the new metal would not last, and that wrought-iron would still remain the best and most economical material. Persistence and increasing knowledge triumphed, however, at last, until now the domain of wrought-iron is practically confined to matters outside structural requirements. When makers were able to show a metal nearly 50 per cent. stronger than iron, produced at practically the same price, engineers were bound to employ it so soon as it fulfilled their notions of reliability. This was not long in forthcoming, and so gradually the present accepted tests and properties were evolved.

That we have now a perfect steel it would be folly to say. It also seems folly to expect that one may be forthcoming. If it were possible to get a mild ductile steel which would stand 100 tons to the square inch, the engineer would immediately long for one to carry 200 tons! All that we can say at present is that *within its limits* we have a very satisfactory article. Unlike the making of wrought-iron, which was largely, if not entirely, empirical, mild steel owes what it is to the chemist. Minute fractions of certain ingredients are quite sufficient to make all the difference between success and failure, and current practice is based upon the results of countless analyses and mechanical tests. We have arrived at this point: it is possible to commercially produce a steel with a very high breaking stress, say 40 to 50 tons and higher; but when we pass a certain limit we gradually lose some very desirable properties. It is not sufficient for our purposes that we should have a *strong* steel; we must also get a *ductile* steel—one that is not "short," is not subject to sudden failure, will maintain its strength under a moderate degree of heat, is perfectly homogeneous, and is free from mechanical defects of manufacture. Our chemistry and practice have not yet got so far as to combine all the virtues beyond a set limit, at least in the commercial sense.

It has been proved over and over again that certain proportions and ingredients produce certain properties of the product, and will always evidence certain mechanical tests. What these proportions and ingredients are depends on the district where the particular rolling mills are situated. It is not essential that every rolling mill in the kingdom should work to exactly the same recipe. Each place has experimented upon and devised its own "mixture" from the raw materials handiest or cheapest to itself. Only in this way would competition be possible. The aim in every case has been to adopt those proportions which would be unfailingly productive of the desired standard of physical tests; for, after all, the mere chemical combination matters nothing to anyone—it is the standard of excellence of the material which is prized and not what it is made from.

However, whilst there are many makers to-day, and many processes, the resulting products are very much in line with one another. And as they are

alike physically, so they agree very closely in the proportionate quantities of their chemical constituents. Matters are now so far standardised that it is matter of common knowledge that more than a certain percentage of carbon, phosphorus, silicon, and other substances acts disadvantageously on the steel. Excess of carbon has the reputation of increasing the tensional strength and hardness; phosphorus results in a "short" steel, which works well but is liable to sudden failure; silicon induces hardness, and is also somewhat similar to the action of phosphorus; manganese increases elasticity and tensional strength, but reduces ductility; sulphur produces rottenness at a red heat and renders steel unsuitable for forging; and so we might go on enumerating the known effects resulting from an abnormal quantity of any one ingredient.

It is therefore necessary that the steelmaker should know the chemical analyses of his ores and raw materials, and he must so work his process and so devise his ingredients that the mixture shall have no such excesses. This is his business and his alone, and the designer has no need to concern himself therewith. Let the latter understand as much of the business as he can, if he will, but it is out of his province to dictate to the steelmaker either how the steel shall be made, or what it shall be made from. To narrow in any way the methods used would be to put a premium on certain districts and concerns where favourable raw material could be cheaply obtained, and to handicap out of the race others whose only chance lay in utilising materials unfavourable to the process selected. All this would of course mean the narrowing of supplies, the creation of monopolies, and the imposition of huge prices. A marketable material can only be obtained by the widest and freest competition in which none of the competitors are handicapped by anything save their own deficiencies.

At the present time there are three accepted standards of ultimate stress for British steels. They are as follows:—that the material shall have an ultimate tensile strength per square inch of original section of (1) 26 to 30 tons; (2) 27 to 31 tons; (3) 28 to 32 tons. The tendency seems to be towards the general adoption of the third case, and perhaps the majority of specifications are drafted upon it; all mills are prepared to work to these figures, and there seems no valid reason why the smaller values should be used. Perhaps the first case—26 to 30 tons—gives a better welding steel than the others, but there is not much in it, and most engineers set their faces against welding mild steel wherever it can be avoided. At all events, so far as can be judged, the third case is the most popular, and engineers will be well advised in specifying these figures.

Of course, whilst the ultimate strength varies the other properties looked for vary also to a certain extent, and it has become customary to test the steel for these by setting a standard of elongation and of contraction of area at the point of fracture. Experience has shown that, if any metal conforms satisfactorily to these three tests, it may be unhesitatingly accepted as being fit and proper for structural requirements. Strictly speaking, each of the

three cases of ultimate strength should be accompanied by its own corresponding standard of elongation and contraction; but it is somewhat curious to note that whilst some engineers do this, yet the great majority specify the same elongation and contraction limits, whatever their ultimate figures may be! This is, of course, only another argument for the adoption of the third case, since if the higher limits may be reached with the same modifying factors, it seems waste to take anything less.

Custom has decreed that a standard of elongation of 20 per cent. in a measured length of 8 in., and a contraction of area of 40 per cent. at point of fracture, are desirable evidences of the right quality for bridge work and all structural erections. These figures are varied a little in different specifications, but not to any serious extent, and since they directly evidence everything which is required, and are readily accepted by the steelmaker without quibbling, they may be taken as a suitable standard. Occasionally engineers have attempted to specify more onerous figures, cases of a contraction of area of 45 and even 50 per cent. having been demanded; but the mills have refused to be bound by such figures except at higher prices, and when busy have declined to entertain them at all. If a uniform product is to be kept up, it is obvious that there must be no departures therefrom for any reason.

Other physical tests which are often demanded are those of bending. Strips are to be cut from plates and to stand bending double on themselves when cold. Or, when heated to a cherry red and cooled in water at 82° Fahr., they must stand bending to a curve with an inner radius of from one and a half to three times their thickness. These are designed to confirm the ductile qualities of the metal, and are certainly of value in that they afford very convincing evidence. If the elongation and contraction of the test-pieces are satisfactory, there is seldom need to further impose more than a few bending tests. It should always be remembered that testing cannot be conducted without money, and sufficient is as good as a feast.

It will, perhaps, be as well to mention here the methods of testing in common use. The question first arising is, "Where shall the tests be conducted?" There are three ways open to the engineer. He may have his tests carried out—

(1) At a recognised public testing-house.

(2) At the rolling mills in his presence or that of his assistant.

(3) At the rolling mills without his supervision.

The choice of which way should depend largely on the magnitude of the work and the size of the order. Since all testing costs money, it should be known that the cost is in the order given above, the least costly way of all being simply to accept the certificates of tests made by the mill's testing staff. In order to check their product all mills have a testing-house equipped with suitable apparatus, which is periodically examined and certified by the Board of Trade. This is used to test bars rolled from every cast, and proper records are kept for filing and reference. Before the steel can be rolled into structural sections, it is tapped from the hearth in which it is made into

ladles, and then cast into moulds to form ingots of from 2 to 4 tons weight generally. When sufficiently set, the ingots are taken from the moulds and carried to the "cementing" furnaces—where they lie under the action of heat until their interiors are sufficiently set, and they are practically of a rolling heat throughout—and from here they are taken to the rolls, and come out in the various desired shapes. Each separate cast is liable, therefore, to differ from the others, and to check this it is the practice to stamp all material as it leaves the rolls with a mark or number to denote which cast or heat it belongs to; as all material from the same cast must be of the same composition, only a few samples from each cast need testing.

For their own convenience and advantage, then, the mills keep records of tests from each cast, and willingly furnish certificates of these to purchasers; so that it is evident that to take such certificates is both the simplest and cheapest way for the purchaser. For their own reputation's sake there is every inducement for the mills to conduct everything fairly. It is not often that any one purchaser (except for large orders) takes the whole of the sectional material from any one cast; and with steelwork going to all the ends of the earth it would be folly to do anything not *bona-fide* on their part. Besides which they cannot afford to vary their product. To be commercially produced it must be of unvarying quality, and to ensure this expensive testing staffs are maintained. For all small or moderate orders the buyer is advised to be satisfied with the mills' certificates, which should always be asked for.

When orders are larger and more important, and it is likely that the purchaser will get the whole of several successive casts, it will be a safeguard to send a representative to the mills, whose duty will be to *see* the tests for each cast of his employer's materials duly carried out, and so be able to vouch for their accuracy. Every facility will be given for this by the makers, and such a course will remove all doubts which may be felt as to the wisdom of letting the maker check his own product. It is perhaps necessary to remark that any man selected for this should be thoroughly conversant with his duties, and of unimpeachable honesty. It is of little or no use to send a junior clerk or draughtsman.

For large and important undertakings it is wisest to combine all the methods. A representative should attend the mills, preferably see the rolling, select his own samples, stamp them with his private mark, and personally superintend their testing. Every precaution should be taken to obviate all errors or chances of fraud. When thousands of tons of material have to be rolled to one order, there might be an incentive to tamper with it, as it would then become worth while. In saying this, it is not desired to cast any reflection on the honesty of any one of our rolling mills. It is well known that the managements would not lend themselves to such practices; but even they cannot guarantee the honesty of too zealous or careless servants; and when the buyer has, through custom, the facility of thus watching over his purchases, he should by all means take advantage of it. As a further pre-

caution, a few samples should be taken from the bulk, and test-strips prepared and forwarded to a public testing-house for an independent report, on independent machines, by independent experts. Should these agree with the inspector's reports and test-sheets, the engineer may rest content that he has taken every possible precaution in the interests of his client.

Test-strips are usually made from cuttings and shearings of the finished material. An occasional angle can be rolled a trifle longer than necessary, and a strip cut from the excess length. A plate can have a trifle cut from its shearings for the same purpose. The only things to watch are that at least two or three strips are taken from each cast, and that the strips are thoroughly representative of the bulk. Many engineers regard a couple of strips from each 10 tons weight of material as being a satisfactory arrangement. When the strip has been cut it must be shaped and prepared for testing, and the manner of doing this is a little varied in different places. The size and capacity of the testing machine is bound to regulate the sectional area of the strip. As a typical example, however, of what the inspector has to deal with the following sketch will suffice:—

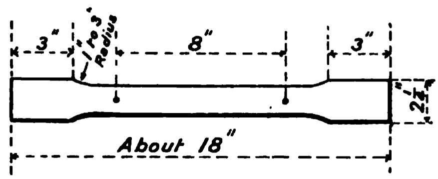


FIG. 1.—Test-strip.

The special point of interest is the part lying between the two dots or centre punches. The width of this will vary according to the thickness of the piece, but for modern machines it is usually 1¼ in. to 1½ in. wide. On being placed in the machine the wide ends are gripped by wedge-shaped arrangements, and a tensional load which can be read from a gauge applied. The load is gradually applied, and gradually increased—preferably by hydraulic means. The gauge is carefully read, and the reading noted when failure occurs. A previous measurement of the piece having been made, the original section is known, and this with the reading is then reduced to tons per square inch. Careful measurements at the fracture will give the contraction of area exhibited, and the extension or elongation is measured off between the dots or centre punches. The whole operation is perfectly simple and calls for nothing more than care and exactitude in measurements. If bending tests are to be carried out, these will be done in a hydraulic press or with a blacksmith's hammer in the ordinary way.

It will now be a little more apparent why specified tests should be standardised and the exhibition of personal predilection suppressed. It is not possible to upset all the elaborate existing machinery for turning out standardised material without largely augmenting costs, and no surprise

need be felt when the steelmaker declines to accept variations. Give him an order large enough, and it may then be worth his while to roll special grades; but for ordinary qualities, such as 99 per cent. of the work of the world demands, he cannot, in justice either to himself or his other customers, tolerate interference. The machinery of production cannot be upset without running very serious risks to its staple product.

The fact that the steelmaker has to be very careful with his analyses of materials used, in order to sustain the level of his output, and that, as previously noticed, the presence of even minute excesses of certain elements robs the material of its desired characteristics, has led certain engineers to fancy that they will further safeguard themselves if they specify a quantitative analysis of materials to their order in addition to the mechanical tests. Now practical reasons against such a course have already been dealt with—if competition is narrowed, prices *must* go up. There is, however, another side to the question. If the steelmaker maintains a chemical staff in order that he may turn out material equal to certain physical tests, and he freely submits to those tests, it does not seem fair or reasonable for the buyer to say that the material shall be of a definite composition within certain limits. The only fair position for the buyer to take up is either that his goods shall evidence their quality by direct tests, or that they shall be proved to be of such a composition as he knows is equivalent to those tests. From such proposals the maker cannot shrink, but it is obviously unreasonable to expect him to submit to both concurrently. In fact few, if any, makers will agree to such restrictions. Most mills will guarantee that their product shall not contain more than certain maximum percentages of foreign elements, but unless they are all to follow precisely the same methods and use exactly the same ores it is impossible to guarantee exactly the same analyses. This ground need not be again covered, but it will be recognised that much subsequent trouble and worry will be saved by the engineer asking only for reasonable proofs.

It is almost impossible to state the actual allowable limits of foreign elements in mild steel. Excess of one is frequently counterbalanced by the presence of another, and so an ideal analysis cannot be stated. It is the unbalanced excess of any one element which ruins the metal, and it is this that has to be avoided, and also renders possible the use of very widely varying ones. As a guide, however, and in order to give an idea of the minuteness of the percentages which mean all the difference between failure and success, it may be stated that modern metallurgical practice sanctions the uses in differing steels of the following amongst other ingredients, and to the extent named:—

Carbon.	Manganese.	Silica.	Sulphur.	Phosphorus.
·02 to ·06	·40 to ·90	·00 to ·05	·00 to ·04	·02 to ·10

Needless to say these elements could not all be present at the same time in the quantities named. They are merely stated as a guide, and from what

has been said it will be gathered that carbon and manganese are always present, and to an extent both necessary and desirable, and that the remaining three are more or less rank impurities which must in all cases be kept down as low as is practicable with the other ingredients present and to conform to the physical tests demanded.

Before leaving the subject of testing, mention must be made of another practice which can only be characterised as bad—that of specifying that additional tests may be taken of material when it is delivered into the manufacturer's yard and is in process of being built in the desired form. The objections to this course are as follows:—Every bridge or other structure requires just so much material of just so many sizes and lengths. The builder orders from the mills only what is necessary, and receives just what he orders. Now, if tests could be taken without cutting up material they might be taken every day during the work on the job if it so pleased the inspector—the only drawback being the hindrance such a course would be. But when some part or other must be destroyed in order to yield the evidence required, the work has to stand until fresh material can be obtained. This is mischievous in the extreme. Mills cannot roll any section at a moment's notice. According to their order-book they have to put in rolls as they are justified, and every mill has a "rolling programme" drawn out for at least a week in advance. Small orders have to wait until others come in which will warrant those particular sizes being produced. Unless, therefore, the size wanted is down for immediate rolling, it may be weeks before such a small quantity can be obtained, and meantime the job must stand! It is no safeguard to order more material than is required, since such sections would immediately become "special" and would defeat the whole object of this "after-testing." When material has once been allowed to leave the custody of the mills, there should never be any further question raised about it; the quality should have been actually and finally settled, and the jurisdiction of the inspector should be confined to surface and mechanical defects of rolling, etc. All steel material should be carefully examined for flaws, defects of rolling, blisters, laminations, and holding full to section. The inspector should gauge all thicknesses, and generally assure himself that the mechanical portion of the rolling has been well and properly carried out.

Although now very largely superseded, yet cast-iron still has a place in structural requirements. It has been fighting a losing battle for many years, and by common consent has at length been ousted from all forms involving the meeting of tensile stresses. Many engineers regret the gradual narrowing of its sphere, and profess to believe that it is not altogether for the best; but when its unreliability in such an important point has been so plainly demonstrated, the average man will not be disposed to re-echo their sentiments. Undoubtedly cast-iron has died before its time—before the *ethics* of stress and strain were intelligently understood; and it is not at all unlikely that the future may again see its revival to some extent, but for the present it is distinctly out of favour. Even so, we cannot yet do wholly without it, and so long as it is

kept in compression it compares most favourably with any other metal. It is again useful when the forms wanted are not such as to lend themselves to being fashioned from steel sections or plates, and when great rigidity and unyielding strength are required. For columns, bases, brackets, machinery, and all forms of ornamental work or overlay it is still unrivalled, and the constructional engineer often has need of its services.

When used constructively it is necessary that it should have a definite measure of strength so that it may be intelligently applied, and, as with mild steel, it is the custom to specify that it shall be equal to certain tests. There is, perhaps, however, even less uniformity as to what are reasonable impositions for it than there is for steel, and it is a little surprising how radically different specifications differ in this respect. One of our largest railway companies, is, for example, content to ask that a 2-in. by 1-in. bar placed edgeways upon bearings 3 ft. apart shall sustain a central concentrated load of 25 cwts., with a minimum deflection of $\frac{3}{8}$-in. Government specifications call for loads of 28 and 30 cwts., whilst private engineers have expected 32, 34, and 36 cwts. even for the same sized bar and loading!

A bar 3 ft. 6 in. long, 2 in. by 1 in., has come to be recognised as the standard test-bar, though some few people prefer one 4 ft. 6 in. long, 1 in. by 1 in., and this they usually specify shall carry 5 cwts. as a central load on bearings 4 ft. apart. The 2-in. by 1-in. bar is by a long way the favourite, and it certainly seems desirable that the load it should be called upon to carry should be more definitely ascertained. The foundry will always vote for 25 cwts., and it will be very seldom that fault would be found with this test. As in steelwork though, it is a question which is the cheaper—a low test and more iron, or a high test and less iron.

The strength of cast-iron varies according to its mixture. Castings are never made solely from one kind or brand of pigs, but two, three, or more different sorts are melted down together. Single brands are weak and unhomogeneous, and good results can only be obtained by the blend of opposing characteristics. Now, there are some hundreds of smelting furnaces in Great Britain, each producing a slightly different product, and by no means at the same price. Since railway carriage rates play a most important part in determining the delivered rates of these pigs, it is naturally the aim of every foundry to utilise, as far as possible, for its work those pigs which can be obtained from the nearest furnaces—only in this way can it hope to compete with other foundries. Consequently, all places get in the habit of working with certain pigs, and bring their castings from these particular combinations to a high state of perfection. Experiments have convinced them that such and such proportions may be relied upon for given results, and it may be that out of the two or three hundred brands actually available they may not use more than five or six to cover their whole range of work. If their cupola tenters and moulders had to use one or two fresh pigs their work would be thrown out of joint for a time, and everyone would feel that they were to an extent working in the dark and with unknown quantities.

It thus comes about that few if any foundries use precisely the same mixtures of metals, and it is impossible, for this reason, to specify that given proportions and brands shall be employed for any work, even though the engineer may be aware that they would answer his purposes admirably. Should he so specify, he must pay dearly for his castings, as he will considerably narrow the circle of competing firms. Foundries in the Midlands use altogether different irons to those in the North or Scotland, and they naturally fight shy of playing with anything they do not thoroughly understand. For the same reasons analyses should not be mentioned. So long as the requisite strength is given, trouble in analysing is both wasteful and productive of no further satisfaction.

This being the case, it is evident that the best thing to do is to settle on such strength requirements as can be most economically and generally met, using the 2-in. by 1-in. bar on supports 3 ft. apart as a standard.

The 25-cwt. limit allows the use of fairly low grade ores, and is in that sense cheap, but it has the disadvantage of being rather lower than the standard in general use for machine and miscellaneous work. Since foundries do not now make cast-iron girders of any magnitude, and their work has gone back to smaller goods, the standard of the metal commonly employed has slightly risen, and it will obviously be an advantage to make use of this. Higher tests can be readily obtained without any perceptible increase of cost, and the engineer might as well make use of them.

When 30 cwts. has been exceeded many foundries will be out of the running, as they could not come up to test without getting specially strong irons. Those places who make a practice of using the latter are not generally the firms who cut prices at all, since their work is of a good character and they pay well for their metals. Thirty-two cwts. is a good test, 34 is a difficult one, whilst 36 is very unusual, and all three will mean the employment of costly pigs and a consequent enhancement of price which will not be in proportion to the extra strength gained.

Looking at the matter all round, 28 cwts. seems a very suitable figure. It is not too high for all good-class foundries to fulfil easily, whilst it is not so low as to be wasteful. No difficulty will ever be found in obtaining proper results, and prices will be in the fair average plane. A deflection of $\frac{3}{8}$-in. with this load will be readily obtained, whilst $\frac{7}{16}$-in. may be occasionally reached, and such results will be very fitting for all average requirements. In cases where higher values *must* be given, they will have to be paid for, and the engineer will not be under any delusion as to the reasons for it.

In testing bars, they are usually placed in a machine designed so that the load may be a dead-weight one. Loads brought on by means of a system of levers are not favoured for pretty clear reasons, and the apparatus in general use is very simple, consisting of a couple of strong uprights, spaced exactly 3 ft. apart, with provision for carrying the test-bar, and tied together with a top cross rail, from which the load is hung. By means of a hand-wheel

the load can be lifted clear of the bar, and gradually lowered on it as often as necessary. The bar bears on thin steel plates placed edgewise, and the load is brought on to it through a knife-edge. The actual weight of the weights used being known, it is the practice when testing to place, say, 25 cwts. on the bottom plate and lower it gradually on to the bar; if this is carried, successive weights of ¼-cwt. each are gently placed on in addition, until the bar breaks, when the load is duly noted, deflection being also observed.

CHAPTER V.

THE SPECIFICATION.

At the present time one of the chief duties of the designer is drawing up a specification for the work to be undertaken. It is, however, a question whether he really appreciates its value in determining the price to be paid for the work. Unfortunately the employment of steelwork in Great Britain has never been regulated or recognised by any body sufficiently strong and representative to codify the desirable or necessary regulations for its use and manufacture. Certainly the Board of Trade and other Government departments have from time to time issued rules for the observance of contractors doing work for them, or for the due provision of safety on public structures, until now each department possesses a standard specification of its own, which is used for all work it gives out, with slight modifications to suit special circumstances; but there has never been the slightest attempt on the part of the Government to draw up a model specification which might be enforced for all work, or even recommended for general use. Indeed, such a course would only be productive of further anomaly, since there is no doubt such a document would be unlike any of the existing departmental ones, even as they are unlike each other! The great drawback to the structural trade as a whole is the immense variety of conditions imposed by the engineer, and the fact that no two sets of conditions are alike. Every job given out is accompanied by its specification, which embodies the pet ideas of its designer, and the first thing the manufacturer wishes to see is what these ideas are. The drawings are quite a secondary consideration with him—it is the specification which more often makes the cost heavy or light and which he is anxious to scan. Of course, by now the different Government specifications—the Admiralty, War Office, India Office, Crown Agents, etc.—are pretty well known, and their names are sufficient for the maker. But the host of other specifications—those issued by each engineer in Westminster and every town and county engineer in the kingdom, as well as every private consultant wherever he may be—are always an unknown quantity until they are read.

It needs a long apprenticeship to structural manufacture before it can be realised how very heavily a specification may handicap a job. Every clause, every phrase and word are carefully considered before a price is finally arrived at. Given the same drawings and details, the same identical design in every

respect, and two specifications drawn up for it by two different engineers acting independently, and it is not too much to say that the prices under open tender by the same firm will in cases vary as much as £5 per ton. The specification is usually looked upon by the engineer as evidencing his knowledge and loving care of his work, and if a man gets a "crank" upon any particular idea, he is sure to embody it in his next specification. The "crank" which looks so harmless and yet promises so much, may cost him £1 per ton for every ton of steel used!

What is the function of the specification? Why is it an institution, and what should it cover?

To answer these questions satisfactorily entails a little retrospection. When the constructional trade was in its infancy such things as tenders for work were unknown. When any undertaking was required, it was placed with some firm who undertook to do the work and charged what they thought a fit price for it. That was in the days when iron firms made money and fortunes were not long in the amassing. Of course the inevitable happened, the goldmine attracted other adventurers, the practice of using ironwork spread because of its obvious advantages over existing methods, and it was soon not so easy to obtain the big prices. Presently the buyer began to want to know how deeply his pocket was to be drained for a given work, and approximate prices had to be named beforehand. Keener competition and increasing work soon saw the birth of the fixed-price tender, and then drawings and details had to be prepared before prices could be named. In order that the quality of the expected work might be made plain to all offerers, short writings describing the same were introduced, and it is these which have developed into the present specifications through the accumulated experience of many men and many jobs. The specification was originally a guide showing the class of work which was to be done, as distinct from the drawings which showed the type to be made, and was instituted as a means of informing the various firms tendering, so that they might each know exactly as much as the other, and thus base their prices on matters of common knowledge. This, then, is the function of the specification.

Why it is an institution has also been partly answered. It must, however, be confessed that human nature is just the same when steelwork is in question as in anything else, and so the specification is also necessary as a means of enforcing the desired quality of work. It would be exceedingly difficult to pin a firm down to any degree of workmanship without strictly defining it. There are innumerable grades of finish and style, and any one of these might be substituted to the profit of the manufacturer without some standard of appeal. It must not be thought that steel firms are rogues ever on the outlook to rob where they can—it is this mistake on the part of the buyer which often causes so much unnecessary friction; but where a job has been let on certain drawings and specification, it is only fair to the unsuccessful firms tendering that the latter should be enforced for the work. In fact, there is everything to gain from a reasonably drawn specification. It shows

the maker exactly what he is and is not to do, and what he is and is not liable for; it obviates all chances of unpleasantness with a rigorous buyer when an easy one was expected, and is a standard of appeal to both parties Well and intelligently drawn, it is a direct help to all concerned and is welcomed by all.

The question as to what it should cover is the vital one, and here the manufacturer and the engineer only too often do not see eye to eye. The first-named deems the specification a convenient means of indicating standards of workmanship—the latter only too often uses it as a stalking horse for a real or fancied hobby. Not that the engineer is purposely a dog in the manger altogether; usually a special clause of his own is put in because he profoundly believes the practice he advocates will result beneficially to his work—he is merely not alive to the added labour and cost his course entails, and through its being no business of anyone's to enlighten him, he only thinks that the market is ruling rather high when his tenders come in. No one would be more surprised than he if he learnt that the high rates asked were directly due to his pet clause and scheme. Succeeding chapters will go into the question of these clauses much more minutely, and it will be seen to what extent conditions of this nature can rule prices.

It will be a safe statement if we say that the specification is primarily intended to define the desired grade of work and that conditions affecting the quality of the material—the tests it must stand and its general appearance when rolled—will find the first place in it. Following these, notes as to the finished appearance of the work, with possibly a brief description and elucidation of any special points, will naturally come. Then it may also be considered that certain questions of methods of manufacture which may have a direct bearing on strengths should be mentioned; and that directions as to painting, delivery, and packing would also be germane. A specified time of delivery with, perhaps, a penalty clause would complete the desirable points of a specification.

Now of these several items the majority are of that class which should never be altered, and are therefore capable of standardisation. There is a commercially best method of doing everything, just as there are commercially best tests. Certainly there are more ways than one of doing things; but if the one way is at least as easy and efficient as the others, and that way is standardised so that men get thoroughly used to it, it soon becomes the best way—best in the sense that it will be done both more quickly and thoroughly because the men concerned have got so accustomed to it. Questions, then, of manufacture as well as of tests are capable of being codified, so that it would only be necessary to refer to them as of such and such a standard. In this sense we are far behind our foreign competitors. In the United States, where the industry is on a very different basis, and the consulting engineer as we have him is unknown, there are standard specifications known as the "Manufacturers' Standard Specifications," and these are freely accepted by all manufacturers. To them is to be attributed in no little measure the alarm

which American competition has recently aroused in this country, since the mere fact of their existence has enabled the maker to lay out his plant and his works specially to be able to fulfil them; and for work in accordance therewith he has consequently unrivalled facilities.

It is this aspect of the question which is not sufficiently well understood amongst us. So long as every specification varies, so long must the maker maintain plant of all kinds equal to coping with all demands. The only possible outcome of this is that British prices must be higher than American ones, even for the same work. The American has but certain fixed laws to follow, and his work must automatically become accepted; the Britisher has innumerable laws—for every job in his yard a different set—and the added cost of clerical work and oversight alone must put him out of the race with his rival. Give the home maker the same or any other *standard* specification to work to, and a very different tale would soon be told. A copy of the "Manufacturers' Standard Specifications," corrected to February 1903, will be found at the end of the book.

It is not expected that the American specification would find favour here; it is so radically different from what we are accustomed to. Yet the Americans have done more steelwork than we have, and their ways seem to answer quite as satisfactorily as ours in practice. It is, however, too much to hope that all our traditions can be upset so violently as its adoption would mean. We must be content to progress much more slowly. Almost any specification, however stringent, would be welcome; the certainty it would give and the opportunity of making special dispositions would quite outweigh other drawbacks. The American one will be found on perusal to be specially laid out to suit quick work and deliveries; its terms are much easier than any British one, yet good work is safeguarded, and it can be distinctly dubbed "commercial" in every sense.

There is everything to gain from standardising all the points which lend themselves to it. Descriptions of work, delivery times, etc., would, of course, always be special to any job; but there seems no valid reason why every separate authority in the land should have its own pet clauses, unless as a nation we particularly wish to pay more for what we get than we need do.

Leaving the manufacturing clauses to be dealt with more fully later, a few observations on the special conditions so often imposed will not be out of place here.

The "time" clause is very frequently the cause of much more being paid for work than need be. Of course, there are cases where time means everything, and where nothing must be allowed to stand in the way of the earliest possible completion. But in reality these cases are few and far between; far fewer than the very stringent clauses so often met with would seem to imply. Short delivery times with huge penalties for non-completion are quite the fashion, and they are recklessly inserted often without any more real grounds than the wish to get work out of the way which has been hanging fire for some time. There would be a deal less to be said against them if the whole

system was different. Work designed in the home market is characteristically slow in coming through, and it is always so contrived that it is bound to be slow also in the manufacture. In no other country are designs so foreign to economy of both time and money to be seen.

So, very often, it happens that the designer or engineer being somewhat busy, his plans do not come through as quickly as they might, and he finds himself dangerously near the times mentioned by his client for completion before he has even let the work. Then a rush must be made, a time clause be fashioned, and a penalty fixed. The result is that the cost is greater, and friction and quibbling are bound to arise. It is only common sense to suppose that the manufacturer is not in the steelwork trade for the fun of it, and that he will make a profit somehow. If, then, he is faced by heavy penalties for possible non-fulfilment, he is bound to insure himself as far as he can, and it is common practice, when it is seen that it would not be possible to deliver in the times named, to include an extra amount in the estimate to cover the fines for the expected delay. Thus the end sought is defeated and the buyer no better off, whilst he gets a "rush" job with its consequent troubles. If a little more expedition had been made with the plans, and a great deal less said about penalties, a much more satisfactory job would have resulted. Given reasonable drawings and specification, the British maker can turn out his work as quickly as anyone; but with the restrictions under which he has to work, it is matter for wonder that so much can be done. The American maker would not look at such conditions; in fact, an American yard could not tackle the miscellaneous jobs which are daily fare in a British yard. There have been many recent examples of American firms running off with British work; but when the order has been secured, the buyer has found that he had to accept *their* specifications and methods of work; and though it would be foolish to say that the finished jobs are not good and equal to what they have to perform, yet they are most decidedly not of that class expected, and not equal, in home eyes, to home work. This should always be borne in mind when foreign estimates are being considered and compared with home ones; if a really reliable guide is desired as to whether our manufacturers are behind their rivals, let ours be asked to give prices on the others' data, or else let it be clearly understood that absolutely the same conditions will be enforced, whether the work is done in this country or not. The results of such a course would be more than surprising.

In some specifications a clause is inserted to the effect that, if an inspector so wishes, he may order the removal of any man or men from the work in hand, and the contractor will be bound to substitute others! Why such an arbitrary course should be thought necessary is hard to fathom. It probably owes its birth to a perhaps well-deserved snubbing suffered by an inspector at the hands of a workman. It should be remembered that an inspector's duties are not of the easiest, and that it needs a capable man to fill the post satisfactorily. Only too often the man appointed is not up to his work, and because of his plenary powers conducts himself the reverse of pleasantly. If

there is friction at a works because of the inspector, it is time to inquire into that inspector's capabilities. Speaking from a long experience from both the maker's and the inspector's standpoint, the author is of opinion that in the majority of cases of this sort it will be found that the wrong man has been chosen to represent the buyer. There are both cantankerous makers and workmen to be found, but they are few and far between. It is so obviously to their interest to be on good terms with the man who has to pass their work, that common sense tells us that they will not readily break with him. It needs an exceedingly well-balanced and level mind to act the inspector's part properly; it is in his power to daily annoy and harass if he so wish, and no man of a petty or spiteful disposition should ever be selected for the work. Least of all should he have the added knowledge that he can insist on the removal of any man he may happen to dislike from the work. His real business is to see that good work is obtained for his principals. It matters nothing to them what the individuality of the man is who has helped in the work; with that they have nothing to do. The question as to who shall and who shall not work for the contractor is surely one for himself alone to decide.

Occasionally, also, clauses are found providing that the inspector shall decide on the quality of the work; that "the degree of finish shall be such as the inspecting engineer shall require," and that he "shall be able to reject any work of which he may not approve." Surely if a specification has any duties, they consist in defining the "degree of finish." The inspector, then, should interpret the definitions to the best of his ability, and not become an independent arbiter able to demand, if he so desires, a finish quite foreign to that intended. So long as such clauses find their way into specifications, so long will makers have to adjust their prices to deal with them. If risks of any nature are to be taken, it is patent that an insurance provision against them must be made.

It would be possible to comment on many other strange conditions occasionally met with, but no good purpose would be served thereby. Sufficient has been said to emphasise the statement that the specification is not fair ground for the display of individual preferences unless the buyer is prepared to pay fully for them. If a reasonable market price is wanted for a reasonable article, then reasonable conditions must be drafted.

In the appendix will be found a model specification, drafted so as to suit British practice and adapted for the best class of work. In it will be found all the essentials considered in these pages, yet it is fair to both buyer and maker. It embodies everything necessary to cover all requisite points, and is recommended as a convenient groundwork for average practice.

CHAPTER VI.

THE DRAWINGS—(*a*) RIVETS.

It is astonishing how few drawings come to the manufacturer from the engineer in a fit state to go straight into the workshops! If one or two Government departments, the principal railway companies, and a few of our foremost consultants be excepted, it may safely be said that 99 per cent. of the remainder send out their drawings either in an unfinished state, or with many errors evidencing incomplete acquaintance with practical details. Although, according to the prevailing system of this country, the manufacturer is not supposed to do any designing, this being in the hands of the consulting engineers and the staffs of the large corporations, yet there are few structural works where a fairly large number of draughtsmen are not kept. It is the business of these men to prepare the drawings received for the shops, and to arrange for the ordering and tabulating of materials required, etc. There are one or two famous works in the country who, through their reputation, are entrusted with the design of peculiar work for which they have made themselves noted; but outside these there are thousands of draughtsmen daily engaged in correcting and extending drawings received, so that they may be in a fit state to go into the shop. This fact argues a woeful lack of knowledge of what is and what is not practical; it is seldom, indeed, that any drawing received from any source can be passed forward without permission having to be asked of the engineer to make some alteration to what has been shown. This entails correspondence, sketches of what is proposed have to be exchanged, and much valuable time is lost. Of course, it may happen that the proposed alterations are to suit the maker's convenience in some way; but, leaving such out of the question, it is remarkable to what an extent it is done.

Now the drawings should, of course, be a true presentment of what is required. The neater and cleaner they are the more use will they be, but they are not *pictures* in any sense; yet that is what a great many draughtsmen try to make them. It should be remembered that platers and template-makers are not artists, and they cannot appreciate beautifully finished and lettered drawings unless they are also clear and precise on every point. The first essentials of a drawing for the shops are absolute clearness, both in lines and figures, and a total absence of everything that is not necessary to their elucidation. No sizes or dimensions should ever be left to scale, but figures

should be placed everywhere; not in one place only, as when the same thing is shown in different views, but every view should be dimensioned fully, so that, in some cases, the same figures may be repeated many times. Time spent in the shops hunting over three or four views in order to find a particular figure has to be paid for by somebody. Dark lining and shading are seldom advisable, except that the latter is sometimes useful to bring out a prominent feature in some view or other; it is only confusing to the workmen to have to sort out the right lines amongst a multitude of shading ones. Plain lines of an even thickness throughout are much more serviceable in the shops. Sectioning should be plain and well-marked, so that each part may be clearly distinguished; as a rule, it is better to do this diagrammatically in thick solid lines than in the conventional hatching. When practicable, flat colours, well chosen, greatly assist in the rapid reading of what is meant; in fact, the *plainer* the drawings are, together with the fullest information of every part and a plurality of dimensions, the more they will be appreciated. Eschew the draughtsman's "art"—let that be left for office copies if you will—but see that everything destined for the shops is as plainly drawn as possible, and cram full of *information.*

Another thing that should never be lost sight of is that the workman is not expected to have, nor is allowed, any initiative of his own in treating or elaborating or extending his work. When, as is nearly always the case, a design is the outcome of exhaustive calculation and much forethought, it would be folly to run risks of any alterations, however slight, being made by a workman, except with full authority from his superiors. Therefore, everything on a drawing has to be faithfully reproduced in the shops, and it follows that, if the draughtsman leaves little details, either because he does not understand them or they are too much trouble, the work will suffer accordingly. When drawings incomplete in this sense, then, are received at the works, the works staff must rectify and draw them out correctly before they can be passed on. It is a not uncommon practice amongst engineers to send drawings of the broad outlines and dimensions of schemes, and request the makers to draw out the details, and submit them to their approval. This is always willingly done, and results are invariably satisfactory; but it hardly seems the correct way of working. The man who makes the first calculations for the work is surely the one to also devise the details to suit.

Amongst the common errors made in drawings, those involving riveting arrangements are, perhaps, the most frequent. Now, a girder is nothing without its rivets; its plates, angles, and tees are utterly useless without them; they may be said to be the most important part of the whole; yet many draughtsmen can successfully negotiate obscure calculations and arrange sections and sizes, but when it comes to a question of riveting they make the most senseless errors! Few days pass in the works drawing office without an instance of rivets being shown in positions where they could not possibly be put in! The designer seems incapable of comprehending that plates and other material must be put together in a certain way, and that

the riveting can only follow suit. He light-heartedly shows rivets in every conceivable situation, and is astonished to be told that they cannot be put in as shown. To design good riveting in any girder is no child's play; it takes a good draughtsman to do it successfully.

When considering riveting there is much to be borne in mind. Take the case of an ordinary web-plate girder—supposedly the simplest form to deal with. Generally the drawing is all made, and then the rivets are stuck in as best they will go, to agree as nearly as possible with theoretical requirements. This is the wrong way entirely. Before any drawing whatever is done, the whole question of the riveting should have been threshed out. It should have as important a position in the mind of the draughtsman as the section required at the point of maximum B.M. On it depends the exact length of every piece of material (if the girder is of too great a span for them to be in one length), the position of the joints, the position of the stiffeners, and very often the thickness of web used. In large girders of the Linville or lattice type, the riveting is on a somewhat different basis, but the present point can be best illustrated by a plate girder in a warehouse or large hotel. Into it trim a number of cross girders at certain fixed points, and a fairly heavy load is carried with a span of, say, 50 ft. In dealing with such a case the draughtsman should first determine his loads, find his reactions and position of maximum bending moment, and then set up his B.M. diagram. When the required flange section has been ascertained and the flange-plate diagram drawn, the shear should be considered and the web tried for "buckling." At the same time rivet diameter and pitch should be worked out, and the web thicknesses should ultimately be settled, not by the shear alone, or the rivets alone, but having due regard to both. Thus the diameters and maximum allowable pitches of the rivets are provisionally determined for all points in the girder before a line is drawn on paper. In commencing the drawing, a faint rectangular outline of the girder should be first made, and on this the centre lines of all fixed points—centres of cross girders fishing in, and all connections—put in. Then must come the consideration of the stiffeners and riveting pitch, and the aim must be to primarily obtain as regular a pitch as is possible. Generally the draughtsman seeks to place his stiffeners at mathematically correct centres apart. This is a mistake. There are few girders, especially those in buildings, of which the moving of a stiffener one or two inches either way would affect the looks. Certainly a symmetrical placing is pleasing to the eye, as also it fits in best (on evenly loaded girders) with theoretical requirements; but the eye cannot judge to an inch or two, and generally it is only this inch or two which is needed to give the rivets a regular pitch. It is a bad plan to place the stiffeners and then space the rivets between as best they will go. Perhaps at a given point a 4-in. pitch is desirable, and through this being done the pitch actually becomes $3\frac{7}{8}$ in. Does the draughtsman ever think of the extra time required by the template-maker to set out a $3\frac{7}{8}$-in. pitch over a 4-in. one? Somebody has to pay for that time, and it is not usually the maker. By slightly moving the

stiffeners the 4-in. pitch might have been used, and the extra time and cost saved.

Of course, the fixed connections may (and sometimes do) interfere with the riveting. If that happens the diameter may perhaps be varied a little and a workable pitch obtained this way. If that does not answer, then choose the best regular pitch and make one or two odd pitches to bring centres correct. It should be remembered that the template-maker has a long steel rule 40,

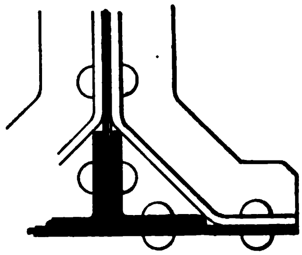


FIG. 2.—Kneed tee.

50, or 60 ft. long fastened to his bench, and that when setting out rivets he brings his frames level with this and marks out with the scriber or pencil and a square. A regular pitch such as 3 in., $3\frac{1}{2}$ in., 4 in., 5 in., or 6 in. is therefore very easily and rapidly marked off, whilst an irregular one involves much cogitation. A single odd pitch may be easily allowed for, and that is why it is advocated. Another point which often upsets riveting is the choice of size of stiffeners. A tee is a very favourite stiffener, but it is a

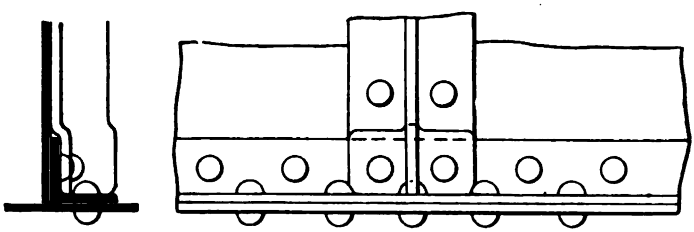


FIG. 3.—Joggled tee.

great enemy to a regular pitch. Where the stiffeners are kneed as in fig. 2, and there is only one flange plate, the tee does not interfere with rivets; but where it is not kneed, but joggled as in fig. 3, the closeness of the two rivets through the tee upsets the pitch altogether. It will be found generally in girders as fig. 3 that angle stiffeners can be advantageously substituted for the tees; they are just as effective for most purposes, and they have, of course, the recommendation of only taking one rivet where the tee takes two. If tees must be used, let the rivets between stiffeners be a regular pitch, so that the centres are not broken, except at the stiffeners.

Since in all girders the points of maximum shear are at the abutments, naturally the rivets here have either to be thicker on the ground or of a larger diameter. Now, the cheapest girders are those with the same unbroken pitch throughout, using the same diameter of rivet all through. Questions of theory preventing the use of the cheapest type, it is imperative that the least expensive arrangement consistent with theory should be adopted in its place. We therefore wish to get as few different pitches as possible, and as few differing diameters. If it is possible to use the same diameter throughout by varying the pitch, it is best to do so; and so we may get a pitch of 3 in. at the ends for a distance dictated by the shear, and then for the remainder use a pitch of 5 in., say. Of course, the fewer rivets required the fewer holes will have to be drilled, and so another saving is effected; otherwise the 3-in. pitch could have been carried right through. If both pitch and diameter must be varied, there should not be more than two differing diameters in the same girder, except in special cases. At all times it should be the object not to exceed either two pitches or two diameters, if economy be a desirability.

As regards choice of diameters, this must to an extent be regulated by the shear and bearing area. For instance, given that the maximum shear on a web be 50 tons and its effective depth 48 in., we may judge that $\frac{3}{4}$-in. rivets would be suitable. The value of one $\frac{3}{4}$-in. rivet in double shear is, say, 5·2 tons, and its bearing value is, given a $\frac{1}{2}$-in. web, 4·5 tons. Since the bearing value is the least, we get a pitch of $\frac{4{\cdot}5 \times 48}{50}$ = say, $4\frac{1}{2}$ in. This is quite a large pitch for the ends of the girders; and so far as the rivets go it looks as though a $\frac{3}{8}$-in. web would do. This would give a bearing value of 3·375 tons and a pitch of $\frac{3{\cdot}375 \times 48}{50}$ = say, 3 in. This would not be too close, and would do very well if the web could be sufficiently stiffened. If, now, the shear was 100 tons, all other data remaining the same, the rivets would not be quite such a simple matter. With $\frac{1}{2}$-in. web and $\frac{3}{4}$-in. rivets a pitch of $\frac{4{\cdot}5 \times 48}{100}$ = say, 2 in., would be necessary; and as this would not be permissible, it becomes necessary to increase either rivet or web, or perhaps both. Try a $\frac{7}{8}$-in. rivet with $\frac{1}{2}$-in. web. This has a bearing value of 5·2 tons and a double-shear value of 7·2 tons. Taking the least, a pitch of $\frac{5{\cdot}2 \times 48}{100} = 2\frac{1}{2}$ in. at most would be imperative; and this not being advisable, either the rivet must be further increased or the web thickened. Try the latter, and take a $\frac{5}{8}$-in. web. Now there is a bearing value of 6·5 tons and a consequent pitch of $\frac{6{\cdot}5 \times 48}{100} = 3$ in. This might be adopted, and it is seen that the web must be at least $\frac{5}{8}$-in. thick, unless the rivets are further increased in size.

The question now becomes, which will be the cheaper course: either to use

a ½-in. web with ⅞-in. rivets (in which case the angles would have to be large enough to take a zigzag or chain-pitch), or to use the ⅝-in. web and a plain pitch of 3 in.? This would be settled by the relative weights of the two

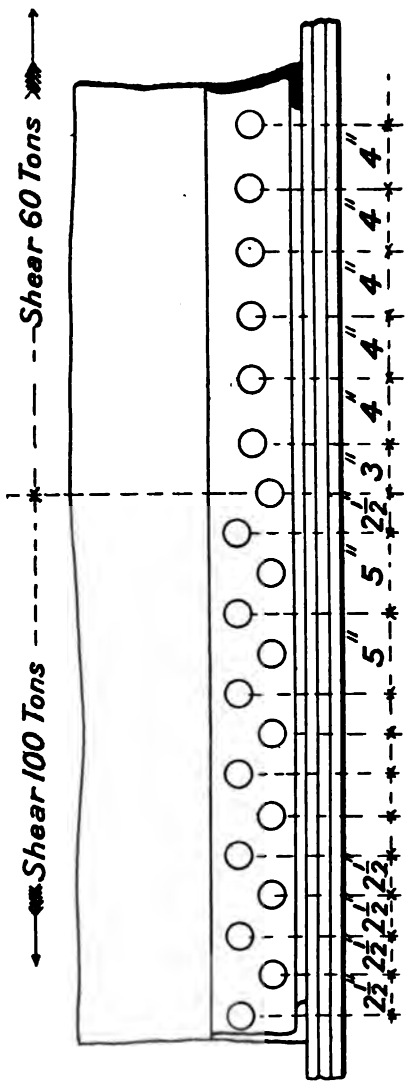


Fig. 4.—Girder riveting with varying shears.

systems. It is probable that the ½-in. web would require quite as much stiffening as the ⅝-in. one, and that there would be no real difference in weights here, so it resolves itself into a question of 5-in. × 5-in. angles and ½-in. web, against the chosen ones of 4-in. × 4-in. and a ⅝-in. web. If they are

made 5 in. × 5 in., the flange plates would not require to be quite so strong, and this would be allowed for. It is almost bound to turn out that the 5-in. × 5-in. angles give a girder of the smaller weight, and it then becomes a question whether 5 in. × 5 in. would suit the connections, the width of flange plates, and other matters with which they have to work in. Supposing it were finally decided to adopt the 5 in. × 5 in., the necessary chain-pitch of 2½ in. and 5 in. would be placed where the shear required it; and where the shear lessened, the pitch could be brought to an ordinary plain one of 3½ or 4 in., as required. The angle would then look as in sketch (fig. 4).

There is another point which must not be overlooked, and that is, that if the ⅝-in. web had been used, it could have been dropped in thickness when the small shear was reached, and so a little weight saved. If this had been done, thin packings would have had to be employed at the angles so as to make up the thickness, or the angles would have to be slightly "sprung" in the riveting. Of course, it might also be arranged so with the ½-in. web; that is, both might be dropped to ⅜-in. perhaps. If the girder was distributed loaded only, or had two concentrated loads symmetrically placed, so that the shear at centre was *nil*, a very thin web plate would be quite suitable. The objections to the practice are that thin packings are not liked in the girder yard, and if only one or two small girders are required, it will be cheaper not to do it; if there are, say, twenty or thirty to be made from the same templates, or the girder is for a large span, the saving in weight would be considerable and worth taking into account. Some engineers make a practice of thus reducing web thicknesses, but for small odd girders the weight saved is more than counterbalanced by the extra cost.

From the few calculations just made it will be apparent that even the exact section at point of maximum B.M. is not always determinable until the riveting has been threshed out. Of course, the nett area required remains the same, but if diameters are altered the material will have to be altered to suit. This does but emphasise the remarks made a little while ago—in commencing to set down a girder on paper, know what the riveting has to be before going too far. Generally the draughtsman goes right forward, arranges his stiffeners, and then—rubs them out again, to duly provide for rivets, or else the riveting suffers in the ways indicated. The riveting should all be set out and centre lines duly put in before a single flange plate has been drawn; then the precise length of each is easily determined.

Since riveting and stiffeners go together, the one modifying the other, minimum centres for the latter should be worked out at the time the former is being considered. When the minimum requisite web for riveting has been figured through, this thickness should be tried for buckling, and by the usual methods the advisable spacing determined. Then when the drawing is tackled much valuable time and trouble will be saved.

It is a poor way of making a drawing to show everything but the riveting and then put a note in one corner to the effect "rivets ⅞-in. diameter, 4-in. pitch throughout," unless the centres of all stiffeners and connections and

their sizes are such that a 4-in. pitch will work in perfectly everywhere. On the other hand, there is no need to go to the other extreme and show every rivet required. The happy mean is required, the aim being not to leave anything to chance, but to give just sufficient information, so that the template-maker shall never be in doubt as to what is meant. In order that this may be so, err a little on the lavish side, since he cannot *see* what is in your mind excepting only so far as your drawing indicates.

A very common size of rivet is $\frac{3}{4}$-in. diameter, and it is the smallest size which should be put in any but very light work; $\frac{5}{8}$-in. and $\frac{1}{2}$-in. are too small to be effective; besides which, they are so small that they are very liable to be burnt in the heating and thus spoilt. For light work they must, of course, be used; but even if $\frac{5}{8}$-in. would be suitable theoretically in certain situations in heavy work, they will be best eschewed. $\frac{7}{8}$-in. is a very good size, one of the best that can be driven, and very suitable indeed for all-round use in medium and heavy work. 1-in. rivets are being used now more than they were, but anything over $\frac{7}{8}$-in. in diameter should only be used when the thicknesses of material are commensurate. $1\frac{1}{8}$ in. and $1\frac{1}{4}$ in. are sizes that are occasionally used, but care should be exercised in employing them, as they take a deal of driving, and are rather apt to be loose in the finished work. All large firms have tackle to deal with these sizes, but not all of the smaller works are as yet equipped; and whilst they can all drive up to 1 in. successfully, they are not all reliable over that figure. It should always be an endeavour not to get the larger sizes in positions where they can only be driven by hand. This latter class of riveting can be very successfully managed when the best labour is employed, but the average is not high. With the advent of machine methods the demand for good gangs fell off, and whilst good men can still be got, yet the majority are not up to much; rivets of comparatively small diameters they can manage very well, but it needs good men to properly snap $1\frac{1}{4}$-in. rivets.

As regards the relative proportions to be observed between thicknesses of plates and diameters of rivets, it is best not to know any rule, since such will only be misleading. Diameters must be suited to the needs of the work. Some men say that they should be reckoned as being double the thickness of the plates less $\frac{1}{8}$-in. By this rule, $\frac{3}{8}$-in. plates would get $\frac{5}{8}$-in. rivets, $\frac{1}{2}$-in. plates $\frac{7}{8}$-in. rivets, and $\frac{5}{8}$-in. plates $1\frac{1}{8}$-in. rivets. Since $\frac{5}{8}$-in. plates can very often be well managed by $\frac{7}{8}$-in. rivets, there does not seem much truth in the rule. It is better to say that on the average $\frac{3}{8}$-in. plates will need $\frac{3}{4}$-in. rivets, $\frac{1}{2}$-in. plates $\frac{7}{8}$-in. rivets, and $\frac{5}{8}$-in. plates 1-in. But this is no real guide, though perhaps it is somewhat more in keeping with current practice than is the one first named. An American rule relating to the pitch of the rivets is not a bad one to bear in mind. It is that in stanchion work or the compression flange of a girder, the pitch of the rivets should not be more than sixteen times the thickness of the plates being used. For $\frac{1}{4}$-in. plates this means a maximum allowable pitch of 4 in., for $\frac{3}{8}$-in. plates of 6 in., and for $\frac{1}{2}$-in. plates of 8 in.; of course all these rules are purely empirical, and with

the exception of the last, which is derived from actual experiments, are hardly worth the paper they are written on. As regards a maximum allowable pitch for girder work, it is not often advisable to exceed 6 in.; certainly this pitch should never be exceeded for any work exposed to the weather, as anything over will not make a sufficiently tight job to keep the elements thoroughly out. For inside and protected work it might sometimes be exceeded, but work with wide pitches is not always so economical as might be thought, and British practice for built-up girder work does not favour more than 6 in.

Calculations for riveting should never be taken too finely. If in jointing

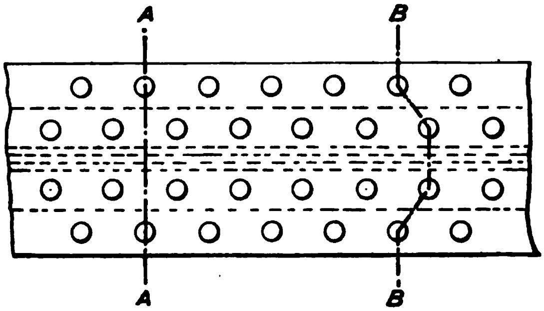


FIG. 5.—New way of riveting girder flange.

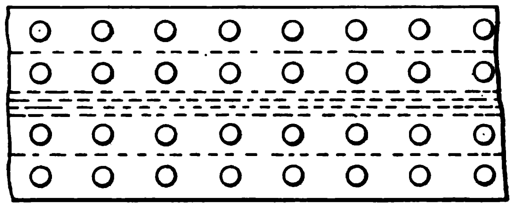


FIG. 6.—Old way of riveting girder flange.

a flange plate it be found, say, that sixteen rivets on either side are just enough theoretically, there is nothing lost by putting in eighteen. A good many engineers are of the opinion that, as a general practice, we are in the habit of putting in too many rivets. Perhaps so; but that is more the fault of taking too low a unit stress. There is no good reason why rivets should not always be taken at 6 tons in shear, with a bearing value of double that amount, *i.e.*, 12 tons per square inch, the smaller value always to be used for quiescent loads. If in calculating pitches it be found that a fractional pitch figures out, adopt the next lowest regular pitch. A small allowance is thus made which will help a little towards avoiding those uncertainties in even the best class of work—burnt, badly formed, or loose rivets. That is why it is counselled that a couple of extra rivets be placed in important joints.

Inspectors do not always detect all the bad work—it may happen that even the girder yard itself does not always know of its existence; and if the bad rivets should come at the joints it might prove serious. By "regular" pitches are meant those ascending by ½-in. at a time; thus, 3 in., 3½ in., 4 in., 4½ in., 5 in., etc., would be so described, though 4½ in. and 5½ in. are not very much used. There are plenty of structures existing in which the rivet stress has been taken at 8 tons per square inch; and where entirely quiescent loads are being dealt with, this may do very well, but it is a high value to use for everyday work. If there is a weak spot in a girder it is much more likely to be in the rivets than anywhere else, and it might prove an expensive job to carry "economies" in this direction too far. A little prudence might some day be worth a great deal.

An error not infrequently made is that, when it has been considered desirable to regulate the allowable stresses on members according to Wohler's theory, and in consequence some of them are stressed perhaps as low as 2 tons per square inch, it is forgotten that the rivets confining those members to the structure, having just the same alternations or variations of stress to undergo, should also be stressed on the low limit. True, their stresses do not alternate from compression to tension, but are always shearing ones; yet the rapid vibrations which are supposed to be so injurious to the one are certainly present also with them, and if such conservative action is necessary with the bar it is also desirable with its rivets.

Although the advantage of riveting girder flanges so that only two holes occur in the cross-section is fairly well recognised, yet we still come across instances occasionally of the old style of four rivets abreast. Figs. 5 and 6 will illustrate the two methods.

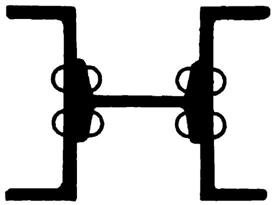
In large flanges with many plies of plates the difference of two holes in the cross-section often means a great difference in weights, and fig. 5 is unquestionably by far the most economical. The only ways in which fig. 5 could fail by the plates parting are as shown by the dotted lines A A and B B. Failure by B B cannot occur so long as the sectional area available along the line is greater than that available along line A A, and care must always be taken that this is so.

Girder sections and arrangements are usually such that nearly all riveting can be done by machine; but very frequently this is not the case with stanchions, and in proportioning a cross-section for these care should be taken that it is looked to. Often sections such as in figs. 7 and 8 are proposed.

These look all right, but if the sections are small, there is not room enough to insert the nose of the ordinary riveter so as to properly get at the rivets. For instance, if the joist in fig. 7 is a 4-in. × 3-in., it would need a special machine to make a good job, and even then, with the flanges being so narrow, the majority of the rivets would almost certainly be one-sided. In planning work due regard must always be had to the tools with which it has to be carried out.

It is hardly necessary to say that the usual rivets used in this country

are "snap" or "cup" headed. Properly speaking, there is a distinction between the two, but in this country we have so mixed them up that they are now



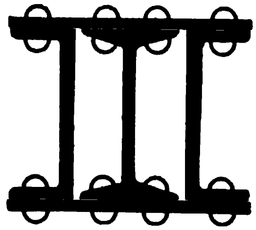


Fig. 7. Fig. 8.
Bad style of stanchion sections.

regarded as alike. The relative dimensions of a good snap-headed rivet are as given in fig. 9. There should not be much rounding under the head, whilst the head itself should always hold full to both diameter and thickness. The snapped end should take a length equal to one and a half times the

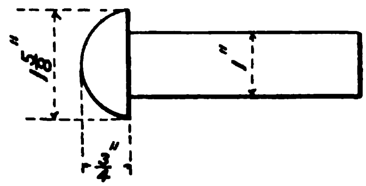


Fig. 9.—Snap-headed rivet.

diameter of the rivet to make it properly. Countersunk rivets always want a little attention, and should never be placed in situations where the stress is in the direction of their length. They have not nearly the strength of snap heads, and are often not very well driven. Their proper relative proportions are given in fig. 10.

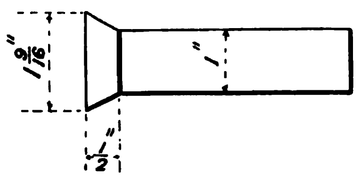


Fig. 10.—Countersunk rivet.

A good system of marking rivets on drawings so as to distinguish them readily is that known as the Osborn. Fig. 11 shows this very well.

"Field" rivets are those to be put in at site during erection, and are shown well blacked, as in the sketch. The system has for its foundation the

diagonal cross to represent a countersink, and the blackened circle for a field rivet. The position of the cross with respect to the circle, inside, outside, or both sides, indicates the position of the countersink. The Americans carry the system very much further, having diagonal strokes to represent flattening of the heads to various heights; but as this practice

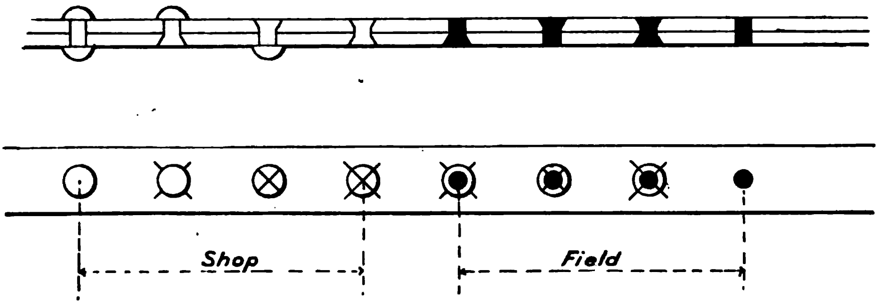


FIG. 11.—Marks for rivets in drawings.

is not in much favour in British circles, there is no need to reproduce its signs here.

Care should always be taken that rivets are not brought too near the edges of plates or bars. The distance between the edge of any plate and the centre of the rivet should not be less than $1\frac{3}{4}$ in. for $\frac{3}{4}$-in. and $\frac{7}{8}$-in. rivets, and for larger diameters it should be at least double the rivet diameter. Failure through the plate bursting at the hole is very liable to occur if this precaution is neglected.

CHAPTER VII.

THE DRAWINGS—(*b*) MATERIAL SIZES.

NOT many designing engineers really know how much the choice of the sizes of their sectional material influences both the delivery and finish of their work. In a vague way it is understood that some sizes can be obtained better than others, but what those sizes are, and why it is so, few trouble to inquire. The real difficulty is that the designer is generally so out of touch with manufacturing needs and possibilities that he quite fails to appreciate the commercial side of the question, and thus cannot see why he should not get a $3\frac{1}{4}$-in. × $3\frac{1}{4}$-in. angle just as readily as he can get a $3\frac{1}{2}$-in. × $3\frac{1}{2}$-in.

Taking a given bridge, it is possible to detail it out in two ways (still keeping the same design), one of which will take from three to six times as long to supply as the other, and yet the weights and sectional areas involved shall be the same. It is not that one detail will take more making than the other, or will occupy any longer in the actual manufacture—there may not be an extra rivet in the whole structure—yet it shall cost anything up to double as much, and take all this extra time to turn out. The secret will lie in nothing more than the choice of sections made.

Good designing does not consist in being a good mathematician. On the contrary, the mathematician generally makes a poor designer, yet mathematics are essential to all designing. They are not, however, *the* essential. A practical man without the trace of a claim to even moderate arithmetic will very often turn out a better girder than another man who has employed reams of figures over his work, simply because he will use his former experience and employ just that material which he knows he can readily obtain. There is a certain fascination about mathematics which draws a man on and causes him to lose sight of the importance of everything save his figures. After being at the trouble to extract certain results to one or two decimal places, it seems sheer waste not to make the most of them and cut and carve everything as finely as they indicate. Yet this is where practical and theoretical designing cross each other. The former involves the use of figures only so far as they help towards an end; the latter is the end itself.

For small and moderate spans and nearly all building work, figures are used more as an indication of what is wanted, or rather as a means of arriving at a minimum possible section, than for anything else. The case is rather

different as spans get larger. In the very largest class of work, say of the immensity of the Forth Bridge, figures must be much more closely worked to. Here the dead-weight of the structure is enormous compared with the useful load, and the main object must be to reduce this dead-weight as much as possible; hence the more important the undertaking, the more place mathematics play in regard to its shaping. But few engineers are called upon to have anything to do with Forth Bridges, and our concern just now is more with the average work to be met with, where the dead-weight of the structure is but a fraction of what it will carry, and where little deviations from figured theory matter nothing to the stability of the fabric. By this is not meant that what is about to be said does not apply to large work; far from it. Even a Forth or a Tower Bridge could be made to cost more than they have done without adding an ounce to their weight, as stated in the second paragraph of this chapter.

With average work the least difficult thing is to determine the stresses on members. This may be done in a very short time compared with that necessary to prepare the complete design. It is the selection of the materials to be used to take those stresses, their arrangement and proper fitting in, the one with the other—the *commercial* side of the design which brings out the skilful man. It is this side in which the steel expert has his great advantage over the average practising engineer or architect. It takes only a fair knowledge of the general principles of engineering to determine stresses on framed structures; but it wants intimate acquaintance with the girder yard and current trade conditions to apply stresses successfully.

Yet there are many points which it will repay the engineer to study. First and foremost, he should know why it is that certain sections can be bought much more cheaply than others, and also be delivered so much quicker. The reason is that the demand for material runs more on certain sizes than on others. The steelmaker, as previously explained, has a "rolling programme," which is, of course, always made up according to those sections for which he receives the most orders. The changing of rolls costs money, and the less changing which can be schemed the better. It is therefore a costly job to put a set of rolls in for a small order, costly, that is, per unit of the weight rolled. If it costs (say) £10 to put any set of rolls in, and the orders to be rolled from that section aggregate 150 tons, it means that the cost per ton of changing has been one shilling and fourpence. If, now, they were changed and there was only 5 tons to be rolled, we at once get £2 per ton as the cost of the operation! So that it is not commercially possible to put any size in when required, and orders must accumulate until their amount justifies the expense of changing.

Thus some sections will always be very readily obtainable. They are favourite sizes and orders rapidly accumulate, and their rolls are constantly going in and taking precedence of less favoured sizes. It becomes best then to employ these sizes when, if there were no such considerations, different ones would be chosen. 6-in. × 3-in. tees and 4-in. × 4-in. angles may be instanced

as amongst the commonest sizes in the market, and they can generally be obtained in less than a week. As an example of the other extreme, $4\frac{1}{2}$-in. × $3\frac{1}{2}$-in. angles and 5-in. × $4\frac{1}{2}$-in. tees may be mentioned.

Roughly speaking, it may be reckoned that 6-in. × 3-in. tees and 4-in. × 4-in. angles can be delivered in a week; 3-in. × 3-in., $3\frac{1}{2}$-in. × $3\frac{1}{2}$-in., and 4-in. × 3-in. angles and 4-in. × 3-in. tees in a fortnight; and $2\frac{1}{2}$-in. × $2\frac{1}{2}$-in., $4\frac{1}{2}$-in. × $4\frac{1}{2}$-in., 5-in. × 4-in., and 6-in. × 6-in. angles and 5-in. × $2\frac{1}{2}$-in. and 5-in. × 3-in. tees in from three to six weeks from date of order. These can be described as the "regular" sizes of angles and tees. For all other sizes usually seen on a merchant's list, it may take anything up to some months to supply. Of course, if a large quantity is wanted of any one size, either regular or otherwise, most makers will put in the rolls for their next programme. Once the week's rolling list is got out it is seldom altered. The quantities are calculated beforehand, and only small or moderate orders can be accepted once the list is out. If a large order comes along it is carried on to the next programme.

If a few bars of a special section are wanted, and none of the mills are putting in rolls for same, the only thing to do is to pay for the change of rolls involved. This may mean anything from a few pounds up to twenty, and, needless to say, makes the total cost prohibitive. Still, if sizes must be had, it may have to be done occasionally. If the special size wanted is similar to but smaller than something which can be more readily obtained, it is a frequent thing to plane the larger into the less and thus secure it. Many times this is the only way of doing it; but this also makes the section cost more than it ought. The list of sizes given as regular sections are really quite diverse enough for all ordinary work, and as they can be bought at the bottom market prices, even if a little metal has to be given away sometimes, it will prove the cheaper policy.

In flats also there are certain sizes more easily obtainable than others. Widths involving $\frac{1}{4}$-in. are not liked, whilst even $\frac{1}{2}$-in. is to be avoided. The most common sizes are 3, 4, 5, 6, 8, 9, 10, 12, 14, 16, and 18 in., but the last three are not always so readily obtainable. In channels there is not so much choice, except that 4 in. × $2\frac{1}{2}$ in., 5 in. × $2\frac{1}{2}$ in., and 6 in. × 3 in. are more called for than other sizes. Zeds are not much used in British practice, and are always difficult to obtain; when required, a couple of angles put back to back will serve quite as well. Plates are always obtainable in all sizes.

If these few sizes were always borne in mind when designing, very much after-worry would be saved. If work is not required in any great hurry, there is no need to stick rigorously to them, a week or two longer will be no great matter. But if work is urgent and requires pushing through as rapidly as possible, contrive those sizes which can be obtained without waiting, and then it is reasonable to expect some expedition in completion. Delays are not the fault of the girder yard when material cannot be obtained from the mills, and it is of small use blaming the British manufacturer for slow deliveries when the remedy lies in the hands of the designer.

Another point which should be attended to is that the number of sections in any girder should be kept at a minimum. Drawings of simple plate girders have been seen in which the top main angles were of a different size to the bottom ones!—sometimes one may see three or four different sizes of stiffeners in the same girder! Such things as these should never obtain in correctly designed work. Main angles and end angles should invariably be of the same sizes; whilst all stiffeners should be alike, except that if a few gusseted ones are required, they should have angles the same as the main ones. Top and bottom flanges are cheaper when made the same widths and generally of the same section.

In lattice and Linville girders it should be the aim to keep the diagonals as much alike as possible. In some types of open-webbed girders under certain loadings there may be two or more diagonals having practically the same stress, but with perhaps a slight difference. The man who is anxious to save weight will cut and pare these until he has different sections for each one. The man who is anxious to save money will make them all alike and sacrifice a few pounds of weight in doing so. Throughout a whole job the same sections should be used as far as possible for real economy. Wholesale slaughtering of tediously worked out figures is not to be understood as now being recommended; all that is meant is that these points should be understood, and then as broad a view taken as possible, so that the utmost economy can be secured.

The choice of the lengths for materials (when the span is over 35 or 40 ft.) also exercises an influence on costs. Up to those total lengths of girder, it is usually best to get main angles and flange plates in one length. If the girder is more than 2 ft. in depth it will be advisable to have the web in a couple of lengths, with the joint at point of minimum shear. But when 40 ft. has been passed joints in flanges and angles also become imperative, and their best disposition often gives matter for much thought. If there are any connections or cross girders or other work fishing in, it will be best to steer clear of them; they also want placing clear of stiffeners, and angles and plates should "break joint" with each other. How to do all this satisfactorily and still manage so that the joints occur as near the parts of least stress as practicable is no light matter. Too many joints mean more work and greater waste of material. Too few mean paying extra for lengths over the ordinary. This latter is a particularly vexatious institution, but it is one that the buyer is powerless to alter. If angles, tees, plates, etc., are over a certain length, an extra price, generally five shillings per ton, is charged to cover the extra labour involved. The regulation lengths, etc., are as under and will serve to guide the reader:—

Angles,	40 to 45 ft.
Tees,	35 to 40 ft.
Channels and joists,	30 to 35 ft.
Plates,	35 ft.; up to about 2 ft. wide.

Since the point of maximum B.M. is generally near the centre of a girder, it is best to keep flange and angle joints well away from here. Since also the point of maximum B.M. is generally the point of minimum shear, the web joints will do very well near the centre. As a matter of economy, all the joints in each tier or ply of flange plates should be brought together, allowing, of course, the necessary lap over each for the riveting. As an illustration of the saving this method effects, the following supposed case is worked out. A flange of six ply (or layers) of plates has to be jointed. The plates are 18 in. wide and $\frac{1}{2}$-in. thick, and the rivets are $1\frac{1}{8}$-in. diameter. As the first step, the number of rivets required either side of a joint in one plate has to be found. For four rows of rivets, staggered pitch, the nett area of one plate will be: $\frac{1}{2}(18 \text{ in.} - 2 \times 1\frac{1}{8}) = 7\frac{7}{8}$ sq. in. The area of one rivet is practically 1 sq. in., and this gives eight rivets as the number necessary on each side of the joint. The joints would then be arranged as in fig. 12 (elevation) and fig. 13 (plan).

From the above it will be seen that on either side of *each joint* the cover-plate has eight full rivets, so that the strength of each plate is maintained throughout. If the pitch of the rivets be 4 in., the total length of the cover required for the six joints will be 6 ft. Now if the joints were distributed anywhere and separate covers provided for each, there would be six covers necessary, each 1 ft. 8 in. long—a total length of 10 ft. The saving made by adopting the plans shown in figs. 12 and 13 is obvious. For very long girders there might be two, three, or more such joints in a flange, and the longer the girder the less attention can be paid to placing the joints at points of least stress—they must come where they can; but in all cases it is possible to arrange to bring the majority of the joints together, and so save weight in cover-plates.

When the girder is so long as to require several such cover-plates, there is not much economy in making the plates up to the maximum allowable lengths—there are other things to think of. In large and heavy girders the assembling of the material assumes sometimes rather formidable proportions, and very long plates are a nuisance to handle, especially at a great height with only one crane available. In some yards one of the first things to be noticed when estimating is the lengths of materials; they may not have room enough to handle 40-ft. plates on a girder of 200-ft. span, though they could manage that length very well if the girder was only 40 ft. long. 25 to 30 ft. is about as long as plates should run in large girders. Needless to say, whatever their lengths, there must never be a joint without a cover being provided. The warning is not without justification, as many draughtsmen have an idea that an over plate will act as a cover to an under one.

Web plates for deep girders should not be in long lengths, as the widths make the plates awkward to handle. The question of cost also is an item. For webs $\frac{3}{8}$-in. to $\frac{3}{4}$-in. thick, the average maximum widths rolled without extras are 5 ft. to 5 ft. 6 in.; consequently, if the girder is deeper than this, its depth will have to become the *length* of the plates, and the webs will have to

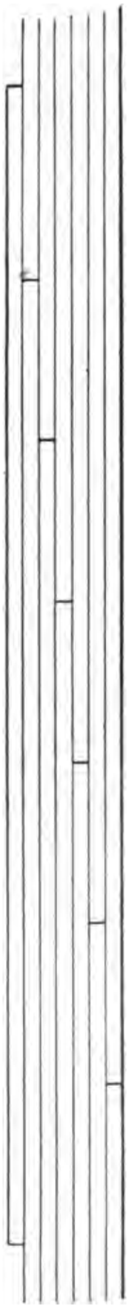


FIG. 12.—Flange joints (elevation).

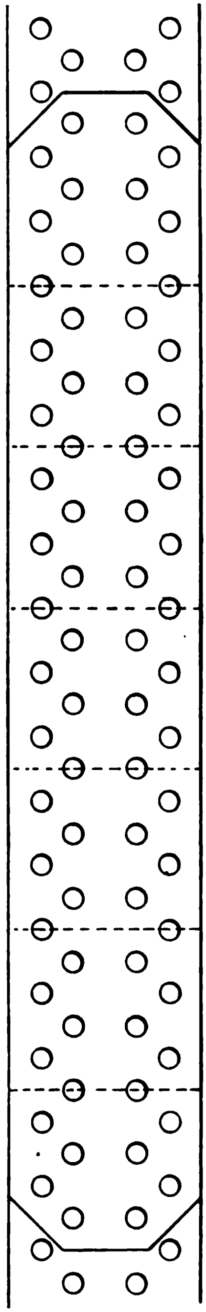


FIG. 13.—Flange joints (plan) showing riveting.

be jointed at the stiffeners. Plates can be rolled up to 7 ft. wide and over, but they are dear at their price, and it pays to joint the web frequently rather than to employ these large widths.

Most engineers will know that thick material is not largely used structurally. Two $\frac{1}{2}$-in. plates are better than one 1-in., and two $\frac{5}{8}$-in. than one $1\frac{1}{4}$-in. The thinner plates are a better quality than the thicker; they are closer and more homogeneous; besides which they are easier to work in the girder yard. It is not often that for ordinary work $\frac{5}{8}$-in. thick is exceeded, either for plates, angles, or tees. Sometimes a $\frac{3}{4}$-in. or $\frac{7}{8}$-in. plate may be used for a web with a very heavy shear and not much chance of stiffening adequately, but they are very seldom seen as flange plates. To go to the other extreme, it is not wise to employ plates that are too thin. It is found by experience that web plates should not be thinner than $\frac{3}{8}$-in., unless they can be adequately protected from the weather and oxidisation. Many cases have recently come to light where thin $\frac{1}{4}$-in. webs have completely rusted away and the girders been rendered useless. $\frac{1}{4}$-in. and $\frac{5}{16}$-in. webs are frequently used for inside work, but they are best tabooed for outside. Neither are $\frac{1}{4}$-in. flange plates a very great success. They do not rivet so well as $\frac{3}{8}$-in. do, and are liable to gape slightly between each rivet. Generally, it may be reckoned that $\frac{3}{8}$-in. is the least thickness which should be used for all-round work. For stanchions and struts thin plates are quite useless, unless the riveting is very close. If, in order to get a shaft with as large a least diameter as possible, thin plates seem the only ones to fit without waste, it will be better to abandon the arrangement and try another rather than to use them. A good cheap stanchion is not necessarily the one with the least weight in it, but the one with the thickest materials for its diameter; if the metal is, say, $\frac{1}{2}$-in. thick, the riveting can be 8-in. pitch with safety, and this means a great gain, since whatever the cross-section selected the riveting is always more awkward than for girder work.

The advantage of using flats where possible instead of plates is not generally appreciated. The market price of the former is always more than that of the latter, but the added planing of the plates quite upsets their initial advantage. Perhaps the most telling thing in favour of the flats is the quicker deliveries possible with them. Although, on the whole, mills can supply plates fairly quickly, yet since all plates come from the same rolls, and there is no changing to be done for different sections, the orders are taken in rotation. Thus when, because of the demand, it is possible to get certain sectional sizes very quickly, yet the more demand for plates the longer it takes to obtain them. If mills are slack, plates in any quantity can be obtained in a few days; if busy, it may be weeks before the accumulated orders have been worked through and it is possible to get them. Since flats are sectional material, certain sizes are readily obtained, whilst a good order can nearly always be got quickly. If flange plates are not too wide—say up to 18 in. for British material—flats are preferable to plates. On the average they will come at least as quickly as plates from the mills, perhaps a little

quicker, whilst the time saved by not having to plane them is often of great moment. A bridge yard cannot afford to have more than a certain number of planers, and should the planed work in be a little more than the average, the machines will soon get behind, and then time is needed before particular jobs can be put on. Even if it be possible to put the plates at once on to the machines, it takes time to plane a flange of many plates, and this time might in most instances most certainly be saved.

There is another thing—flats will weather better than plates. Planed edges invite oxidisation, whilst the rolled skin on the edges of flats is in itself a protection. A tier of flange plates viewed at a distance of two feet certainly looks neater and more precise when planed; but if viewed at a distance of a dozen feet it is almost impossible to distinguish which is which. How many girders or bridges are seen at such close quarters? The majority of railway bridges are never even noticed by the general public, whilst very few would know the difference on road bridges. Structural work for buildings is seldom in sight, and presents a good opportunity for economies of this nature.

In jointing angles it is necessary to use covers, and these must be "round backs," as they are termed, through the outer corner being rounded to fit in the inner corner sweep of the main angle, as in fig. 14.

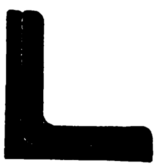


FIG. 14.—Jointing angles.

Now, there is no need to insist on these covers being rolled as round backs; to do so means an infinity of time and patience, as the demand is necessarily so small. The girder yard should be allowed to plane them out of larger sizes, or round the corner of a stock angle, as they find best. So long as the designer gets his required sectional area, he has no need to be insistent on the letter of the law.

Most engineers will recognise the advantage flats have over rounds in principal and roof work. The difference is not so very apparent on light work of small spans—eye and fork ends can be readily and cheaply stamped for $\frac{1}{2}$-in. and $\frac{5}{8}$-in. rods, but as diameters increase the cost runs up by leaps and bounds. Some years ago it was the correct thing to use only rounds for the ties of principals, and this work used to average £18 to £20 per ton. To-day, by the use of flats, work of the same spans is worth only £10 to £12 per ton. Smithwork of all kinds is very expensive, and necessarily so, for it is slow and tedious. It is much more graceful looking than flats, and also appears lighter perhaps; but that is all the advantage it possesses. Principals are seldom on a level with the eye, and at the height most of them are it is difficult to see by which method they are made. If the flats are confined at their extremities by bolts such as the rounds are, then their economy is somewhat discounted, since they must either be given larger ends or a great deal of metal must be sacrificed in their lengths. But if rivets are used, there is very little waste, since they may be so arranged that only the diameters of one need be taken away to arrive at the effective cross-section. In larger

principals they are especially economical. The cost of making a 3-in. end-eye or middle is very great, whilst the welding of a 3-in. bar is no light matter. If flats are used there is no welding, there is no forging, only a slight increase in weight. Often the same width of material can be made to do duty for nearly all the members, either by increasing the thickness or the number of parallel pieces. The large pins and bolts of a round-rod principal are a very expensive item. They must generally be turned and their holes accurately bored, or else they are not accounted satisfactory. Rivets are always cheap, and are a rigid and excellent fastening.

One of the absurdities of principal building still lingers: that of providing gib and cotter joints, or screw ends as the case may be, so that the bars may be properly tightened! So soon as a principal takes its seating, its ties are immediately tensioned, and there is small need for any arrangement for drawing tighter. At the same time, if the work has been properly done, there should be no need for any adjustment before the principal is set to work. If templates have been properly made, each principal is a replica of its fellows, each joint and rivet or bolt is in identically the same place. An adjusting means is only an apology for bad work, and should not be tolerated. It is an added expense, and is at the same time a disadvantage.

The thickness of the material chosen also counts for much. It is best to stick to even eighths where possible—$\frac{1}{4}$-in., $\frac{3}{8}$-in., $\frac{1}{2}$-in., $\frac{5}{8}$-in., $\frac{3}{4}$-in., $\frac{7}{8}$-in., and 1 in., etc., should be the thicknesses ordinarily used. Occasionally it may be necessary to employ an intermediate sixteenth, but caution should be used and the engineer ought never to be guilty of using thirty-seconds. The puerility of using fine differences of thicknesses is seen when it is remembered how much latitude is often taken in fixing the working stress. In some members of railway bridges, where the unit stress is based on Wöhler's theory and is a low figure, it is a temptation to cut as fine as possible, because of the very lowness of the stress taken. Yet, were the draughtsman engaged on a steel building, and his unit stress was, say, 8 tons per square inch, he would think very little of a slight increase of area in a member if it improved matters. But if Wöhler's theory is worth anything, the 2 tons it may allow is on precisely the same footing as the 8 tons of the other case, and there is just as much reason for using marketable sizes in the one case as in the other. If a lattice girder be taken of an ordinary size—100 to 150 ft. span—nice calculations would no doubt show that minute differences in areas could be made between, say, some of the centre diagonals, and it might occur to the draughtsman that he could conveniently do this by varying the thicknesses of bars. Of course he could, and the results might be that some bars would be $\frac{1}{2}$-in. thick and others $\frac{15}{32}$ (such bridges *have* been designed!); and by this means perhaps 2 lbs. of material has been saved on the bar, and the draughtsman prides himself on his "mathematically correct results"! Such refinements do but cause the practical man amusement, tempered with annoyance that any man should be so dense as to catch at a sprat and miss the whale. The use of fine thicknesses does but prevent the ready obtaining of material, besides giving

the yard untold trouble in sorting and placing. Any labourer can tell the difference between a $\frac{3}{8}$-in. and a $\frac{1}{2}$-in. bar, but it takes a good man to detect a thirty-second difference in mild steel, even if you give him calipers to use. The buyer has to pay for all vagaries of this kind. In estimating, it is known which designs will give the most trouble as well as the most work to the yard, and they are priced accordingly.

CHAPTER VIII.

THE DRAWINGS—(*c*) FINISH.

WE have now to discuss what is, perhaps, next to the specification, *the* most important fact in determining costs. Properly speaking, finish belongs to both drawings and specification, and cannot really be classed as belonging solely to either one or the other; but since the drawings do, at all events, illustrate many types, it will be convenient to say something about it here. It is all the more important that the true relative position of finish to costs should be understood, since its bearing is not quite so obvious as is the difference between 4-in. and 6-in. pitch of rivets, or the several sizes of material. When a man has never had to actually do any given work himself, he cannot be expected to form an accurate opinion of its work. He has no knowledge to aid him in an estimate, and he is just as likely to choose the more difficult work as being the easier, as he is to make the right choice. More probable still, he will be apt to forget that there may be any differences at all, or that it matters which way any work is done.

The latter, at all events, seems the only explanation of the prevailing attitude of the designer. At the present time practically only two styles of work are recognised by him—the plain and the ornamental. The first is understood to be utilitarian work pure and simple, and the latter a flowery treatment or overlay of the first. Beyond these two distinctions few men seem to go to-day, and the matter is one for great regret, since not only has it cramped our trade and stereotyped our plans, but has directly led to the capture of many markets by our competitors. It is rather strange how the Britisher clings to old traditions of work, despite the changing times. It can hardly be because he wilfully shuts his eyes to what is going on around him; he is not really stupidly obstinate, rather must it be that it is a lack of thought, a want of reflection, and because no one has drawn his attention to the real cause of it hitherto. He has been looking at other things; has been suspecting the British workman of degeneracy and blaming the British manufacturer for want of enterprise, never dreaming that the matter really lay much nearer home. Let our designs be altered—not in principles, but in details—and our specifications recast in a more rational manner, and then it will be time to blame the manufacturer and his men if we still lag behind.

The amount of "ornamental" structural work which comes through annually is a negligible quantity as compared with the mass of purely utilitarian. There is a certain quantity which is primarily the latter and is supposed to be shorn of some of its crudities, but even this is as nothing compared with the steelwork which is made for a purely commercial object. Most men know that when they begin to "ornament" they also begin to spend money; but few appreciate the fact that nearly as much money can be literally wasted on work which is frankly commercial in conception and does not in any way pretend to partake of the ornamental. The difference in value on such work may be as much as four or five pounds per ton, due solely to the "finish" which has to be put upon it. This is a broad statement and these are telling figures, but it is within the author's knowledge that the amounts stated are far below the actual figured differences on work let within three years of the date of writing.

In an earlier chapter it was laid down that the designer's duty was to utilise the money placed at his disposal to its utmost advantage, whether the work was plain or florid in character. If for a strictly commercial object, then not a single pound was to be spent which would not directly earn dividends. If this be so, then one of the first questions which confronts him will be, how far is he to go in exacting "finish" on any particular work. By "finish" is meant the practice of making the work agreeable to the eye in addition to fulfilling the demands of stress and strain.

One of the first axioms for cheap work (cheap only in the sense of not costly) is to do away with all superfluities. Everything not absolutely essential to the stability or safety of the structure should be rigorously excluded, and only those things included which play a vital part in the design. The next axiom should be that what is deemed essential should be constructed and arranged in the simplest and most direct manner known.

It will be convenient to mention several practices which do not conform to either of the above enunciations, and which have therefore in the past done (and are still doing) harm to British trade by unduly handicapping it against the foreigner who has been wide awake enough to steer clear of the pitfalls himself.

On certain standard drawings now and for some time past in use, the diagonals of lattice girders fit snugly into the roots and along the flange of the main girder angles, and the specification makes special mention that this must be so, stating that the ends must be "filed and chipped" so as to be a perfect fit. In the first place, what special purpose does this "perfect fitting" serve, and why is it preferable to cutting the diagonals off just proud of the root of the angle? Figs. 15 and 16 show both ways.

So far as can be judged, there is no theoretical advantage gained by fig. 15 over fig. 16. The extra $\frac{1}{4}$-in. of length is not required for the riveting—the main angles being $4\frac{1}{2}$ in. $\times$ $4\frac{1}{2}$ in. give plenty of room without this. The rivets are in all cases carefully proportioned to take the tensile or compressive

stresses sustained by each bar, so that even the struts do not need the support of the angles at their extremities. The fact of the bars well butting on the angles does not help in any way against racking, nor does it stiffen the girder in any respect. Does it really look any better, even? Could the difference be detected at a distance of five yards? On the average, taking one size with another, it costs sixpence per end to properly dress into the angles, over and above the cost as in fig. 16. That is one shilling per bar. Do these shillings help the girder in any way? Will they make it stronger, safer, lighter or add a single day to its life? Will they save a single rivet or a pound of weight in any member? The engineer does not exist who would venture to

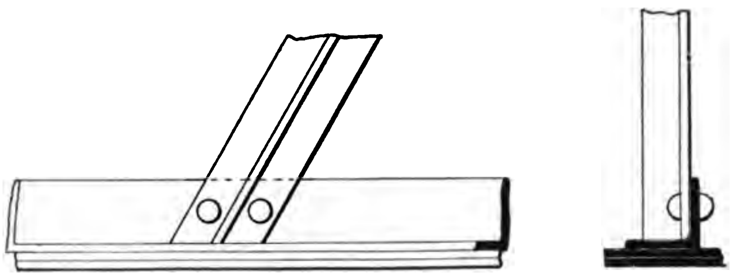


FIG. 15.—Diagonals of girders (wasteful method).

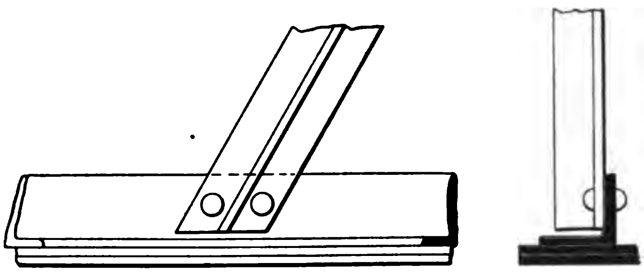


FIG. 16.—Diagonals of girders (economical method).

disturb his calculations in any way because he had specified such "engine-work" fitting for his girders. Yet these are the questions which should be asked regarding every stipulation of this nature. These girders are for solely a commercial object. Their whole business will be to aid in the expansion of trade, and yet they are handicapped by an unnecessary amount of capital being spent on their production. Another well-known specification insists on diagonals being cut $\frac{1}{8}$-in. proud of the angle flange, but to be well chipped and filed into the root of the angle. Whether fig. 15 does or does not give any advantage, certainly this last course, which is midway between 15 and 16, loses it and still falls short of the gain in 16. It has all the failings of 15 and just loses the advantages of 16. There exists absolutely no good reason why fig. 16 should not be adopted, and the ends of the diagonals left in the condition in which they come from the cold saw.

Chipping and filing is often required on the ends of kneed stiffeners, as in fig. 17. The slight marks left by the cold saw are objected to, and the ends must be smoothed and made perfectly flush with the flange plates. The corner that is nipped off must be dressed and filed up until it might be thought that a sliding contact surface was being made. Each end done this

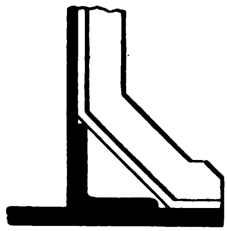


FIG. 17.—Finishing of kneed stiffeners.

way will cost sixpence to ninepence, according to size; and then when the girder is finally perched in the air, it will only be the birds that will know about it! The edges of the stiffener should come flush with the plate anyway, because it costs no more to do this with proper tools than it does to have them either projecting or a little proud; but a saw finish is clean, and if the corner must be taken off, the shears will do it very satisfactorily, and there is no need to do more so far as honest work is concerned.

Often cleat connections are shown on drawings to follow the contour of the joists they are fastening. Fig. 18 will illustrate. It is hard to say what the precise idea is. It cannot be that with the flanges butting perfectly on to

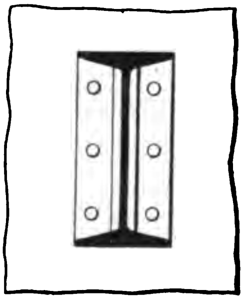


FIG. 18.—Cleat connections (wasteful method).

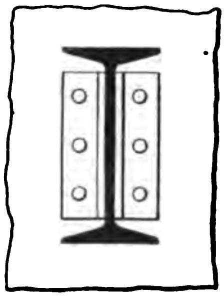


FIG. 19.—Cleat connections (economical method).

the cleats, the latter are meant to carry the load this way; because sufficient rivets are put through the web to properly transmit loads. Then what good purpose does it serve, and why is it better than the method shown in fig. 19? There are just as many rivets got in, and yet the cost of the cleats in fig. 18 will be more than double those in fig. 19, without the slightest advantage being gained. This same principle can be applied to numerous other cases

where every precaution is taken to ensure proper strength in one direction, and then apparently neglected in favour of, or rather supplemented by, additional complications.

Another thing often done is to show the angles of rail-bearers and small cross girders returned at the ends to form end angles (see fig. 20). It looks rather a neat idea to do this, and there does not seem any objection to it. Neither is there, except on the score of expense. Frequently these angles do not lend themselves to "press work"—especially if there be only a few of them required and the whole has to be done by hand. There are two knees and two joggles to each angle, the latter being both ways. Compare this now with fig. 21. Here there are only two joggles in one bar, the rest being

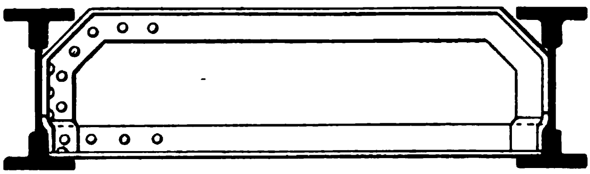


FIG. 20.—End angles of rail-bearers (wasteful method).

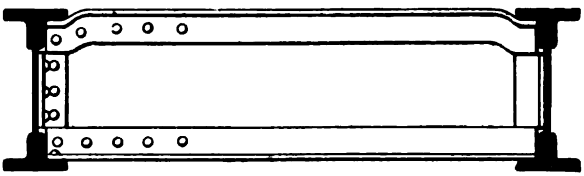


FIG. 21.—End angles of rail-bearers (economical method).

perfectly straight. Yet fig. 21 is just as efficient a job as fig. 20, and is anything from half a crown to ten shillings cheaper in workmanship alone.

It should be remembered that all curved lines are expensive in structural steelwork—concave more so than convex. The only way in which the girder yard can produce these is to use the punch or shears and then hand-dress—a tedious operation. It is a very common thing for connecting plates, as in figs. 22 and 23, to be shown with curved sides, the draughtsman never realising that he is in any way adding to the cost of the work. Yet the first will be from threepence to a shilling, and the second anything from a shilling to three shillings more than if all the lines were straight and simply sheared. The girder yard does not possess any patent tool which can turn these plates out to any desired outline irrespective of cost. They all have to be laboriously chipped and filed by hand.

Many draughtsmen delight in the hogback or the fish-bellied girder, or one with rounded ends. Figs. 24, 25, and 26 illustrate them respectively in outline. They are generally supposed to look a little better than the plain rectangular girder; besides, they are reputedly more scientific. Are they? If it is

scientific to spend as much money as possible, then they are so; if, however, it is scientific to carry the greatest load at the least expenditure, then they

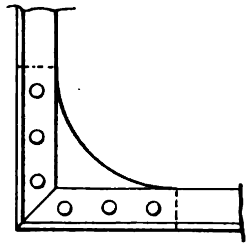


FIG. 22.—Connecting plates (wasteful method).

are decidedly not so. The labour costs on figs. 24 and 25 are usually fifteen shillings to a pound more per ton than if they were rectangular; and on fig. 26

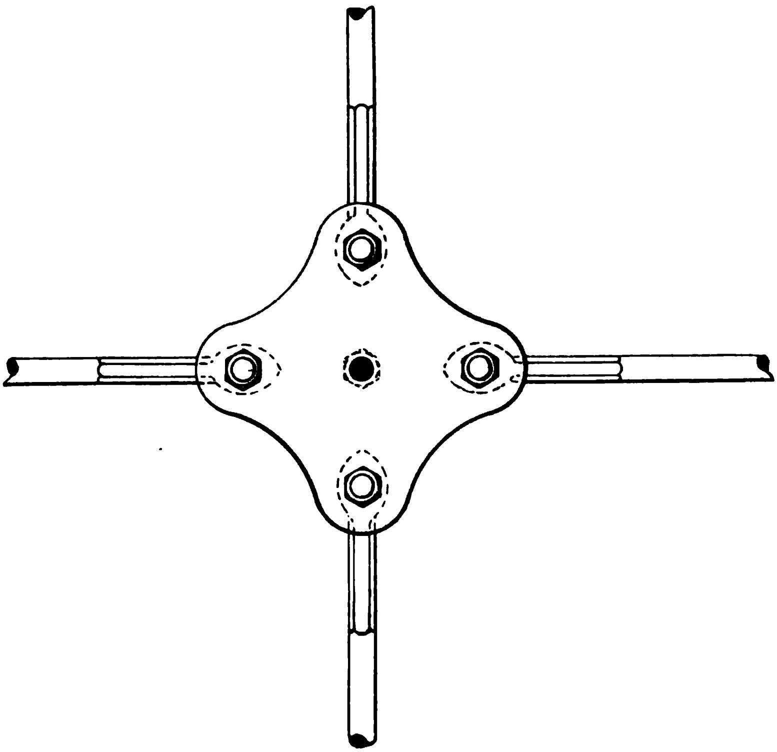


FIG. 23.—Connecting plates (wasteful method).

about ten shillings per ton more. The few cases where circumstances demand, for good reasons, any one of these types are few and far between; they are

most usually adopted at the draughtsman's whim without the slightest thought to the money which would have to be paid for them. Designing steelwork is not child's play; there is not room for such irresponsible decisions; neither is it a field for the unrestricted gambols of theory. *Practice* must be the arbiter, and theory and play must both give way to its teachings, or wastefulness is bound to result.

Many open-webbed girders are often shown with a curved-top boom, and the remarks just made apply equally well to these. Of course, when the curve constitutes a distinct type, as in bowstring girders, exception cannot be taken. It is to what should be rectangular girders which are "beautified" by curves that what is said applies. Linville girders have often been made with curved-top booms, and the cost has been met without, perhaps, the slightest inkling that a little less foolishness would have considerably lessened the bill.

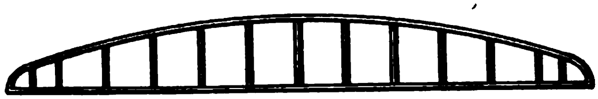


FIG. 24.—Hogback girder.

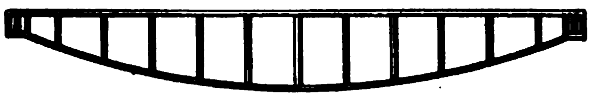


FIG. 25.—Fish-bellied girder.

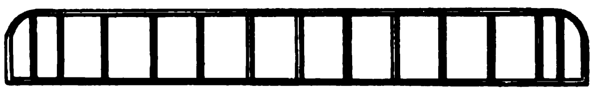


FIG. 26.—Round-ended girder.

It would be possible to illustrate numberless other of these special fads which have grown up and fastened on to our steel trade, like so many leeches; but no good purpose would be served thereby. Enough has been said to show that any deviation, however small, from what is necessary only augments the bill to be paid, without giving any real benefit in return. Every little joggle, every knee, every curve, every rivet beyond what is necessary or advisable, is so much sheer waste of good money—a squandering of what might be so usefully spent elsewhere. The draughtsman should be continually on the alert to watch that he has not unconsciously gone a little way further round than he need have done in accomplishing any object. A knee costs more than a joggle, and a square knee or bend as much as both put together. It is a very safe axiom to beware of the fire; any operation which depends on fire and heat is bound to be expensive, and consequently to be avoided as much as possible. A certain amount of smithwork

is necessary for almost any work; the practical man eliminates as much as possible, and his skill will be evidenced in direct proportion to the results.

A point about which there has been much controversy is that of drilling *versus* punching rivet and other holes. Much has been written on the subject, and it has been conclusively demonstrated that, should punching in any way damage a plate or other material, the damaged part does not extend beyond an $\frac{1}{8}$-in. into the plate beyond the edge of the hole made. Thus, if a hole be punched $\frac{1}{2}$-in. in diameter and then reamed out to $\frac{3}{4}$-in. diameter, the whole of the damaged portion will be removed by the reaming operation, and the resultant hole and the material around will be in exactly the same state as though it had been drilled through the solid at first.

Punched work is in disrepute in Great Britain. Few engineers will now tolerate it, although at one time it was the only method used in metalwork. In this country everything must be drilled or punched and reamed, yet across the water the condition of things is entirely reversed. In the United States there is very little work which is drilled, and controversy as to whether their practice is right or wrong is practically unknown. There the whole question the designer sets himself to settle is how to "get there" in the quickest and cheapest way. At the same time he is not to be surpassed for his skill in designing; on the whole, he uses more figures and calculates to a greater degree of nicety than we do ourselves; he is just as tender of the moment of inertia, the radius of gyration, the section modulus, and all the other latest refinements of mathematical lore—indeed, he is responsible for some of them; he is in the habit of facing and solving greater difficulties on the average than engineers of any other nationality; his spans are greater, his depths deeper, and his heights higher than the usual—yet he still punches his materials. On some pettifogging span of 20 ft. a British engineer will have a specification pages long, insisting, amongst other things, on "all rivet-holes being drilled from the solid." An American will make and confidently put up an Atbara Bridge with a specification of only a few clauses, and no mention whatever of any other method for making rivet-holes but punching!

Drilling from the solid with present tools and appliances is a wearisome job. Whether the mechanical engineer will ever make the process commercially possible or not is a question. Just now it is too tedious to be really within the range of practical work. Certainly it is often enough specified—it is very seldom done, however. If insisted upon, it does not take the engineer long to realise that, if his job is at all large, he will have to wait a very long time for it; and it is soon tacitly agreed that punching small and reaming to size will do just as well. The number of holes in a moderate-sized girder which have to be put in the material is enormous, and time is necessary—whatever the method—to get them all in. Even punching is slow, but it is still incomparably the fastest; punching and reaming stand next; whilst solid drilling stands quite in a class by itself. As a

rough-and-ready comparison it might be stated that the comparative rates are about as 1 : 2 : 3.

It is due to the theoretical man that punching is out of favour. The author does not know of any authentic indisputable records of tests which will prove that built girders with punched holes are weaker than similar ones with drilled holes. Inferences are, perhaps, to that effect, but mere inferences prove nothing. The weakened area by punching is very small given an average pitch, and is certainly of no account wherever there are compressive stresses. It is questionable also whether with good hydraulic riveting there is much difference in tensile members. Let it be allowed, for the sake of argument, that there may be a slight disadvantage, what is there to hinder a slight additional area being put in to make up for this? That is virtually what the American does. He reckons his $\frac{3}{4}$-in. rivets as though they were in $\frac{7}{8}$-in. holes, his $\frac{7}{8}$-in. as though in 1-in. holes, etc., and is quite satisfied that he has taken all precautions prudence demands. What is the difference in area between $\frac{3}{4}$-in. and $\frac{7}{8}$-in.? The one is ·4417 and the

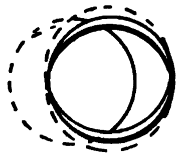


FIG. 27.—Holes before reaming.

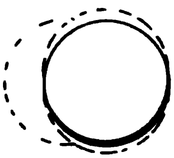


FIG. 28.—Holes after reaming.

other ·6013 sq. in. If the flange is on the average $2\frac{1}{2}$ in. thick, with four rows of rivets so placed that only two come abreast, the addition of ·798 sq. in. to the sectional area would have the effect of meeting and providing for any weakening when $\frac{3}{4}$-in. rivets are used. If the girder be 40 ft. long, this would mean an addition of less than 2 cwts.; or taking steel at £6 per ton, of about twelve shillings to the cost of the metal. The difference between punching and reaming on such a girder would probably be between £2 and £2, 10s.!

For large and important work, where it is necessary to reduce the dead load to the smallest proportions, it will be an advantage to punch and reamer to size; but for the thousands of tons of small work made annually—small bridges, small girders, stanchions, and steelwork for buildings, etc.—there exists no good reason against the practice of punching.

One fault which punched work used to have—that of bad holes—is eliminated by modern methods. Fifteen and twenty years ago it was no uncommon thing to see odd holes through several thicknesses with perhaps half or more of their area covered by some intermediate plate through which the hole had been carelessly punched out of centre. When this happened a reamer or drill was put through, and the hole cleared out so that it would admit its rivet. Before reaming, the hole would appear as fig. 27; after the

operation, as in fig. 28. This certainly helped to give punching a bad name, since it appears on the face of it as though the rivet through fig. 28 could not be doing half the work it ought to, and that it was receiving very unfair treatment from some of the plates. Although it is doubtful whether the contention could be substantiated, since in theory no account whatever is taken of the frictional value of the contact of the plates, yet it is not good work; and since good work can be done at the same price, there is no reason why anything but good work should be tolerated.

In those days flange and other plates were mostly marked out from templates by means of small tubes the same diameter as the rivet holes. The tube-end was dipped into a mixture of pipeclay or whiting and water, and on being passed through the holes in the template and pressed on the plate, left there its impress—a white circle. This served to mark the position of the hole to be punched, and at the machine the puncher (operator) guided the plate under the punch as accurately as he could. These men got very expert at their work, and it was remarkable how little they deviated from the right position, though virtually they only guessed at it every time. Still, some errors were bound to happen, and if an unskilled man had to be put to the machine for any reason, the results were not exactly happy.

This is now changed in favour of "nipple"-punching. Here the positions of the holes are accurately determined from the templates by centre-punching by hand, and in some works boys are employed to use the old tube and whiting method to surround these punched dots with circles so that the puncher may readily find them. The punch on the machine has a small nipple in its centre, as in fig. 29, and this nipple finds the centre mark on the plate, the hole thus being bound to be correctly centred. The method is really old and is of British origin, though it is popularly supposed to be American and of comparatively recent importation.

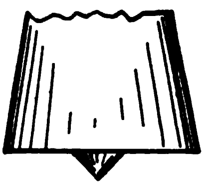


FIG. 29.—Nipple punch.

Good punched work should be so accurate and well put together that a mandril $\frac{1}{16}$-in. less than the diameter of the holes should pass freely through them. It is not only possible to get this, but it is commercially practicable; so much so, that engineers are perfectly warranted in specifying it, and works everywhere will readily accept it.

In riveting this class of work the rivet should be upset in its entire length so as to completely fill the several holes, and a good solid job is then assured and one about which there is no need to fear. If engineers reverted to this plan of specifying work they would be surprised at the difference it made to their prices. On some work punching is cheaper than reaming by twenty to thirty shillings per ton, and these are figures which tell heavily in even a moderate-sized job. With proper precautions there exists no good reason for the present boycott of this method for a good half of the work turned out annually. Where many plates come together, as in heavy

flanges, there may perhaps be a greater show of reason for the reaming process; but where only three or four thicknesses have to be fastened, punching is quite equal to the work. For drilling through the solid no good word can be said from the practical standpoint. It is admittedly the ideal method, but it is not yet within the range of commercial structural engineering.

Reverting again to the broad definition of finish, and considering first the unseen work, the unobtrusive useful foundation upon which the completed structure has to be erected, or the skeleton giving stability and solidity to its walls or floors, it may very pertinently be asked, What justification is there here for "finish"? There is nothing to delight the eye, for nothing is ever seen once it gets into position. No one can quarrel with its appearance or take exception to its outlines, yet in some structures many thousands of pounds are buried in finish, and money has been freely spent which never will and never can benefit anyone. Of what use is planing, chipping, filing, and dressing in such work; what interest will it pay and how much longer will it make the structure last? Some time ago our best-known railway company was very pushed for some warehouse work—the room and accommodation was badly needed, and orders were issued to push the work through without delay. There were some 2000 tons of heavy box girders in the basement—each with five and six ply of flange plates. They were plain, straightforward work, and could be turned out at a great rate, the only hindrance being the vast amount of planing to be done. All girders were specified to have flange edges planed and to be neatly dressed all over. The planing machines became congested, and, after some argument, the engineer was induced to dispense with planing and dressing, the work to be otherwise of exactly the same standard. The immediate consequence was that heavy deliveries were possible, and the huge warehouse was erected in record time. The manufacturers agreed not to charge by the actual weight put in, but on calculated weights to the finished drawing dimensions. Of course, many tons more of material were put in than were ever paid for under this arrangement; but the compact suited both parties, since the one got what it wanted—quick delivery, and the other got a huge turnover, but with a diminished scrap-heap. The girders were out of sight when erected—they have never seen daylight since. Is there anyone bold enough to say that they are a pin the worse for not being carried out according to the original specification? On work of this class much lower prices can be secured by dispensing with finish of this nature. So long as the job is thoroughly sound work its appearance matters nothing, and it is real folly to ask more than this. Makers will always be glad to quote lower prices and to only charge on calculated weights; since, though they lose the scrap, yet the planing time is saved, and money can be thus turned over very much quicker. All boxed or covered-in work of every description can be treated in this way. There is no need to do anything but shear the edges of plates, gussets, brackets, and angles; straight lines should be everywhere, and the only thing to be insisted upon is good, in the sense of honest, workmanship.

There is, however, much work which, though in view, is akin to that which is covered up, in that it is too far away to be distinctly seen—it is only the broad outlines which meet the sight, the details being obscured by the distance. High roofs (either in public halls or over station platforms), railway over-bridges or viaducts, aqueducts, and bridgework for new and only recently explored territories may be mentioned as typical instances. Often in such work the most careful filing and dressing has been tucked away and no one is a penny the wiser—but the shareholders are so many pounds poorer. If the provision of this minute fitter's work helped towards the stability or life of the structure, then there would be good reason for its inclusion. But it does no such thing; it does not help in the slightest in any useful direction; it is just so much waste, since its presence can be neither seen nor felt. True, the designer knows that he spent pounds on planing and dressing and tinkering, and that it is a "good job," as commonly understood, and one which "will not disgrace him," but it is more than probable that he is the only satisfied party in the whole transaction.

Now, there are sheared surfaces and sheared surfaces; there is good work and bad and slovenly work. It must not be imagined that in advocating the least expensive work shoddy work is meant. Nothing is further from the point. It is possible—commercially possible—to shear edges in a very fairly straight line, one free from kinks and insets of the blades, and one with a perfectly cleanly cut edge throughout. It is this type of shearing which is meant. The usual margin given by the manufacturer to the mills for plates is $\frac{1}{8}$-in. all round. Thus if a flange plate should plane nett at 30 ft. long by 16 in. wide, it is ordered as 30 ft. $0\frac{1}{4}$ in. long by $16\frac{1}{4}$ in. wide. If the mills send the material in weighing more than $2\frac{1}{2}$ per cent. than it should do, calculated to the last-named dimensions, whether by exceeding the specified thickness or breadth or length, they lose the extra weight sent, this being the only margin allowed. Material sent in under size is returned and not paid for. This evidences how closely mill shearing can work, and it is a fact that in a flange of six to eight ply of plates put together in a good yard, it is impossible to say whether planing has been done or not at twenty feet and less away. The matter is different when foreign plates are used. These vary in widths sometimes as much as three inches, and it is impossible to use them without reshearing or a large amount of planing.

It might be objected that sheared edges would be difficult to paint and so preserved against oxidisation. If the shearing was ragged this would be so; but just as scabbed plates would not be allowed, neither would ragged shearing. In practice it is not found that well-sheared edges are difficult to properly protect. They take a little longer to paint, it is true, but they have no other drawback. Neither do they need repainting more often than the rest of the structure. So far as maintenance goes they are equally as long-lived as the neatest of planed edges. For all practical and theoretical reasons "fine finish" is not an essential either to honesty of manufacture or service when in use.

Taking, next, work which is essentially utilitarian and yet in full view of the passer-by, such as road-bridges, foot-bridges, columns and low roofwork for stations, piers, landing-stages and the like, the question as to the degree of finish advisable broadens somewhat. According to our insular notions, nothing should be looked upon unless it has an engine finish. This is not commerce, however, and the day is not far distant when our bridge designers will have to recognise, in common with the makers of agricultural implements, that just as well-cast toothed wheels are good enough for a mowing machine, so rolled sections and machine-made rivets are good enough for ordinary structural requirements. Hard facts and the stress of competition have generally obtained the whip-hand in the past—they are good taskmasters.

However, to meet the prejudice of the day, let us consider the essentials for this class of work. The first is most certainly that calling the work into being—the needs of trade. Money is to be ventured and money must earn dividends regularly; therefore capital must be conserved and no waste take place. The mere structural requirements of strength are to be first complied with, and then the disposition and selection of the metal so arranged as to give the maximum degree of required finish at the minimum of extra cost. Take the case of railway station roofing supported on stanchions. The shareholders will be content with bare necessaries; the passengers will be attracted by appearance—to an extent. Just how ornate the character of the work is to be the directors must decide. Let it be a busy place in an important centre, then, according to present standards, the designer will be justified in asking for all edges to be planed, all frazes neatly removed, rivet-heads properly dressed, clean work throughout, etc. All work in view, at any rate, must be up to the accepted standards of good (apparently) workmanship. There must be no protruding edges of stiffeners, and gussets, joints, and butts of every description must be perfect and regular. It is, however, incumbent to see that the *form* in which the work is made is of the cheapest, so that the requirements just enumerated may not be too heavily drawn upon. Lattice-work stanchions will cost more than solid ones. Roof girders with curved booms will be more expensive than with straight ones. Curved brackets, connecting plates, and stiffeners cannot be put up for the cost of straight ones. Flats do not require planing, flat bar-ties are cheaper than round ones, riveted principals cost less than bolted ones, angles are the cheapest sectional material which can be bought, tees the dearest, hand-riveting should be avoided, awkward sections for riveting should not be used, and all the means at command which will tend to reduce costs, save that of sacrificing finish, should be employed. Although it should be attractive, a railway station is not a hotel, and ornamentation of structural work will not earn dividends. The appearance of York Station is admittedly very fine, and it contains some good specimens of what cast-iron is capable of; it is a thorough credit to its designers and builders in every sense, and is often pointed to as the model of what a good station should be. But is it strictly so? If it had cost £50,000 less, would it have earned less money or been of less service to the railway

company? The whole of its present proportions could have been kept, and yet it might have been so put up as to have saved £2500 annually in interest for shareholders. It is of no use nowadays expecting the public to patronise barn-like places or to condone glaring architectural faults; that is well known. But there is all the difference in the world between providing good, clean, airy, light accommodation in keeping with the canons of taste, unobtrusive in appearance, but giving a sense of space and cleanliness, and in overlaying all this with florid ornamentation and specimens of work to the glory of the designer and builder. The latter is apt to have so much style about it, and to have so many corners and excrescences that it is well-nigh impossible to keep it clean; and financial considerations prevent a coat of paint too often. The former is plain but dignified, is clean and will keep clean, and has not so much about it but that requisite painting can be done at the proper intervals. Plenty of light, plenty of space, and plenty of paint are what the modern railway station requires.

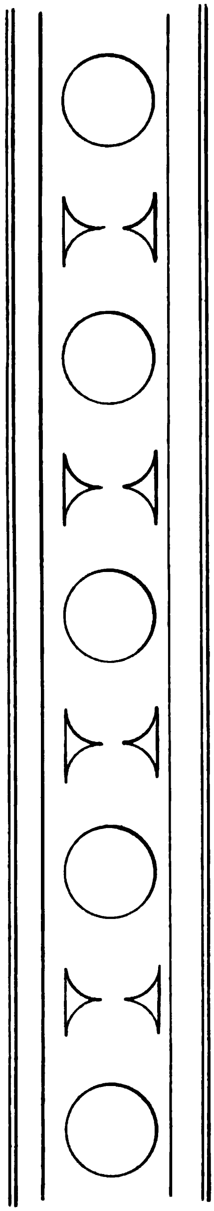


FIG. 30.—Fancy patterns cut in solid webs.

There is one form of work which is particularly objectionable to the maker—that of making solid web girders and then piercing the web into fancy patterns. Fig. 30 will illustrate the point. There is nothing good which can be said of this type. It is neither pretty, ornamental, nor useful. Add to this that it increases the cost enormously, and a little of its puerilities will be understood. If the holes are too large to be punched at one operation, it means nipple-punching round the edges and then hand-dressing with chisel and file. According to the weight of the work it will bring up the cost from two to five or six pounds per ton in itself. A desire to lighten effects is probably the motive for it use—it admirably succeeds in lightening pockets.

Another practice which may be instanced here is that of placing rosettes or stars at the junction of bracings or girder diagonals, or distributing them wholesale wherever there seems a clear spot. Such devices are not worthy of engineering, and they are but mentioned to be condemned. Fortunately, both these and the piercing mania are apparently dying out.

The keynote, then, to success with work which is commercial and well in

sight is "keep down the costs by attention to the form and design of the work." A requisite degree of finish is considered necessary, but it should be of the type outlined at the commencement of this chapter—a reasonable degree, suited to the facilities of the manufacturer, and that can be effected without ruinous outlay or even any very great augmentation of costs.

Now we come to feature work, or those designs which in themselves challenge the attention, and are obviously meant to invite criticism or praise because of their form or beauty. Great public works or monuments, exposed steelwork in sumptuous buildings, memorial bridges, or indeed any work in which the designer has been given a free hand to indulge his fancies, and where money is but of secondary account. It is in work of this nature that the stickler for finish should find a congenial vocation. By all means file and chip and polish and make a mirror surface if that is part of the design. Take no account of the wastefulness of curved lines or round rods, or of the comparative costs of plates and channels and angles; never mind about the quarrels of punching and drilling, and be altogether superior to questions of rivet and stiffener economy. Run the chance for all it is worth, and indulge in every whim which can be conceived. If money be of no account, then raise such a monument as shall bear witness to the designer's merits so long as one piece shall hang to another.

There is one thing, however, which will probably detract, after all, from the pleasure such work gives—mild steel is not inherently beautiful, and its rolled shapes are bound to vex an artistic soul. Most probably in the end it will be found that most, if not all, of it in the design is covered up and hidden from view in favour of a more artistic material. How are the mighty fallen! the strength-giving ribs, the foundation of the fabric—all alike are banished from sight, and possibly squeezed to allow even more to be devoted to outside embellishment.

It would be infinitely better to recognise that there is no beauty in the material itself. It is not like cast-iron, it cannot be moulded into any form; it is not like wrought-iron, it does not take kindly to much tinkering. It is just itself, a personification of strength, but lacking in every grace. It has a dignity of its own, a consciousness of power; but of prettiness, nothing. Beauty of outline it may have imparted to it, but only at the surrender of its virtue—strength; beauty of detail, it is impossible to endow it with. It is essentially a commercial product, and it cannot be purged of the taint of its origin; it was made for everyday use and it is not practicable to exalt it to a superior station.

Severity of outline accords with its dignity, because it follows natural laws. Outside of the straight line and the arch it is out of place and not in keeping with itself. It is the medium of usefulness and service, and not of ornament. So soon as the engineer and designer sees this clearly, so soon will he have done with attempts at the impossible either in design or workmanship. It is too noble a metal for the debased uses to which it is so frequently put, and its nobility lies in service for which it is pre-eminently and entirely adapted. It is absolutely utilitarian to the last molecule, and nothing will ever render it anything else.

CHAPTER IX.

INSPECTION—I.

It is not everybody who can make an inspector. Most men think they can do it well—until they try; then a few are honest enough to admit they are not cut out for it; others burke the question and try something else. The very few stick to it mainly because they cannot get anything else to do. It is not one man in a thousand to whom the work is congenial and who adopts it because he likes it and is successful.

The position of an inspector of work and materials is one of the most equivocal ones it is possible to find. He must either be of brass, inflexible and unswerving, or of that calm judicial temperament which, while able to take a comprehensive and unprejudiced view, is capable of enforcing its deductions without regard to anything beyond its own conclusions. The man who hesitates, the nervous, highly sensitive, or impulsive man, no matter how highly principled and desirous of doing the right he may be, will never make a good inspector. Just as the lazy, happy-go-lucky, or unprincipled man is not fit to represent his employer's interests, neither is the man who is timid and retiring, however capable he may be. An inspector has to meet a great variety of men, most of them experts in their trade, for the purpose of judging their work; and there is much latent hostility to criticism in all human nature. It needs an even temperament to get on with men who plainly regard one as a necessary nuisance, and often untold patience has to be exercised. There is no middle course: either no rebuffs of whatever nature must take effect, or the disposition must be so well balanced that suspicion and opposition are at once disarmed. Of the men doing inspection to-day, the vast majority are of the first category; it is the very few only who can be classed in the second.

It should be at once said, and said plainly, that the inspector *must* have served his time in the shops. The office-bred man never yet made an efficient inspector; he is too heavily handicapped by that which he does not know, and which is only to be learnt as a man in the shops—the freemasonry of labour. He does not know what should and what should not be looked at; he has not the workman's view, the workman's standpoint, but is continually treading where he should not, and overlooking or passing by that which is

vital. Books never yet taught handicraft; they may guide it and direct it, or suggest and point out, but they cannot make the mechanic's hand, or endow it with its intuitive skill. Mere reading, mere study, however thoroughly entered upon and pursued, cannot make up for the loss of practice; neither can years of office work impart as much as one month of the shops. It is only intimate *personal* acquaintance with the methods of work which can give authority to expressed wishes or opinions. The amateur is always known in the shops. He cannot hide his obvious rawness. He has an air of unfamiliarity which he cannot shake off, however hard he may try—his very walk will betray him.

The whole effect of this upon the journeyman is not hard to forecast. Every word uttered by the inspector is heard with suspicion; his blame is discounted, whilst any praise is received superciliously. What he has to say carries no authority so far as his opinions go, and is only listened to because of the power behind it. No workman takes kindly to blame for his work even when expressed by his acknowledged master, whilst an amateur's criticism only provokes his scorn. The timid, uncertain man can be badgered or talked into anything; he will give way in the end through sheer weariness. The man whom nothing can hurt, who has no feelings to be wounded or susceptibilities to be trodden on, can pursue his own path despite everything. True, his ways are as often wrong as right, but so long as he has faith in himself he will get what he thinks he wants, either in work or in kind. No man will be so deceived or so flattered; and he will pass more bad work than any other type, for the workman or foreman will strive to take him in—they thus get "some of their own back," to use their own phrase.

To be successful in inspection it is imperative that a man know his business thoroughly. He must have the journeyman's knowledge with the master's power of putting himself outside the work and judging it with a complete understanding of all the facts, tempered by a very certain notion of the standard which can and must be attained. A man may have the faculty of observation developed very highly, and if he has once seen a thing never forget it; but unless he knows work from the toiler's view, he cannot be capable of forming just opinions on the facts before him; he can but compare the present with the past, and as no present is exactly like any past, he is at a loss to know how to deal with the difference. An office-bred man may act as an inspector for years, but he will never, unless he actually comes to the bench or the floor, be able to hold a candle to the man who knows work intuitively. He may be boldly sure of himself and his own judgments, or uncertain because of his consciousness of shortcomings; in either case he will not get the work his employer desires; he does not know how.

Neither is the wholly practical man always a success in this capacity. He is bound to be better than the purely theoretical man, but often his education has not fitted him to meet on an equality men reared in more prosperous circumstances. It needs a very level head indeed not to be turned with the flattering attentions paid when the manufacturer or manager thinks

he knows his man. If either adulation or contempt is likely to effect the desired purpose, the inspector will not lack for either. Not only this, but the purely practical man can only see with the works' eyes and the workman's imagination, and must fail to take the broader view necessary to the buyer. The man who makes anything lives in altogether a different world with regard to his work than does the man who buys his wares. Each can only see his own end of the matter, and fails altogether to appreciate the other's motives. The inspector, in order to do justice to both, must take an equal appreciation of the standpoints of both, or his decisions are bound to be unsatisfactory to all, besides being without the elements of common fairness. A successful inspector must have the minutiæ of the works at his finger-ends and the wisdom of the world in his head. His thorough integrity must be without question.

The essentials of inspectorship are not generally understood or appreciated by those responsible for its employment. It certainly seems a very simple thing to send a man to look at a girder, a column, or a bridge, or to post him for a time to watch their manufacture. On the face of it, it is easy work, and why should the best man that can be found be paid a high rate for it? It is much cheaper to send a low-money man to idle his time away! So it appears until we get below the surface of things. *If it were not for the general high standard of honour amongst manufacturers in this country, little of the work now doing duty would be worth more than scrap price.* So far as the effective policing of work is concerned, the average past and present inspectorship is a farce. Men there are to be found who are conscientiously and uncomplainingly doing their duty and using their great gifts and knowledge at a woefully insufficient salary; others, and the majority, are honestly trying to do what seems to them right, yet lack the necessary knowledge to ensure the ends sought; whilst a few are rogues pure and simple, fattening on both sides, and passing and certifying anything so long as it is made worth their while. If a maker or a foreman really wishes and tries to get dishonest work passed, even the most acute of inspectors will hardly detect his tricks; how, then, shall a man who does not know the secret of those tricks be able to do so? The commonest gloss and make-up will serve to deceive the inexperienced, but the devices of a clever workman interested in passing off some little fault need a workman's care to detect. If manufacturers were so minded, it is not too much to say that bad work could be passed off wholesale on customers without any attempt at corruption of officials specially detailed to detect the same.

A man who has laboured to make himself as thoroughly conversant with work as has been here outlined cannot be got for two to four pounds a week, unless he is the victim of circumstances. Neither should it be expected that he could. The position is one of great responsibility—if it is worth anything at all. As the size and complexity of a job grows, so naturally does the responsibility, and yet it is quite a common thing for a man with three pounds a week to be in charge of work costing his employer tens of thousands

of pounds! If the manufacturer can be trusted, why should even that small amount be unnecessarily spent? Is it for the sake of spending money or what? If he cannot be trusted, and it is an essential to have someone in residence, must not that someone be entirely capable of his work, or else is he not worse than useless, since his presence inspires a confidence which is continually being betrayed? If bad work is feared, and it is to be presumed this is the case, or inspectorship would be unknown, the man for the work must be as well informed thereon in every way as the acting manager who is doing the work, and who is in the receipt of a salary ordinarily from four to ten times as large as his. It is not the amount of hard work as measured by the sweat of the brow which an inspector performs that should be the measure of his remuneration, but the responsibility he has and the knowledge he must have gleaned in order to enable him to use his powers for his employer's benefit. Until the status of this calling is considerably raised and salaries radically altered, the best class of men will never willingly enter it.

It might very well be objected that this is a plea for spending more money on work. It is nothing of the sort. It is a plea for common sense. If the general level of inspectorship was higher, manufacturers could quote lower prices. At the present time a considerable factor in influencing prices is the personality of the engineer and the probable inspector. It is no unusual thing to hear in the estimating department the remark that the engineer of a certain job is so and so—"He's all right; but —— is the inspector, so you'll know what to expect"; and prices are adjusted accordingly. It does not take long to size up each man's character, and the probable expense to the firm with any man can be very nearly set down. The more ignorant and incapable or otherwise troublesome man he may be, the more must they cover themselves to protect against his known failings. Few makers desire to turn out bad work; not many men are so constituted that they can take pleasure in this, and for this reason a good man is welcome. He will not make unnecessary trouble; what he has to say will be merited, and there will be nothing to fear from ignorant judgments. It is known he will be fair. Such a man is worth doing work for, and prices can be safely brought in line.

Whatever his attainments, the first maxim of every inspector must be to carry out the specification. On the drafting of this must be based his own conduct. When a maker has tendered his prices on certain information supplied him, it is nothing but fair to both parties that known conditions should be properly carried out. Let there be no hesitation on this score. Whilst the manufacturer has his rights, yet these cannot in any way traverse specific undertakings, such as he enters into when he takes the work. Young officials often feel reluctant to insist on conditions which, though set down, hardly seem equitable. This is not their lookout, nor has it anything to do with them. If the works and the buyer care to mutually enter into an agreement, the buyer's agent is there to see that the works properly carry out their assigned duties. But with all this comes the second maxim of inspectorship, "to carry out duties as agreeably as possible to the maker." The proper

course for every man confronted with apparently abnormal conditions is to stick to his specification or instructions until further orders arrive, but at the same time immediately acquaint his principals with the pros and cons of the matter, stating his own opinion and, at the same time, attitude, and asking that if anything is to be modified he may be advised. On matters upon which he has discretionary powers, he should exercise his judgment immediately and not bother his principals unnecessarily. Great firmness and tact are essentials in such situations. Blustering assertions are not worth the breath they cost. There is always a "right" about every matter. There is no other course honourably open but to choose it.

There is a vast difference between the man who does his duty quietly and he who does it with a trumpet. The red-faced, loud-voiced assertive man, however upright, can never be the success the quieter self-respecting man will be; nor will his full-toned utterances excite half the respect the more quiet delivery will inspire. Most men who are at the head of any establishment, whether as owners or managers, are there because of ability and fitness. They hold their position by means of their innate worthiness and their confidence in themselves. Such men are not to be frightened, or even impressed, by arrogance of any type, whether justified in part by acquirements or not. Attainments they can and do respect; but they respect them the more they are accompanied by the knowledge that other men have brains. It is but right that an inspector should show every courtesy, even as he expects it, and he must in turn respect those with whom he is dealing. His duties are to get the work made as well as his instructions indicate, and to see that no action or word of his either hinders the execution thereof or causes attempted fraud. He must therefore make himself as agreeable as possible to all parties.

Given that the drawings and specification have been drafted, estimates called for, and a tender accepted, the first of the inspector's duties will be to proceed to the mills to inspect and test the materials. The manufacturer will communicate with him, and inform him at what mills the steel is to be rolled, and if he so requests, furnish him with a copy of the order, giving the sizes and lengths of all materials. As the time of rolling depends on the state of the mill order-book, the rollers will inform him when they will be ready for him; or if his specification obliges him to see the actual rolling, the days when his attendance will be necessary. In some cases, this is done through the buyers—the girder makers.

It is not necessary that the rolling should be seen unless the work is very large or of a special character. The bars, etc., to the order will be collected, and when there are sufficient to warrant it the inspector is sent for. Armed with his private stamp, he selects lengths from which the test-pieces can be conveniently cut, and either stamps them himself or sees a man do so. The test-lengths are then prepared, *i.e.*, cut to size, and shaped somewhat as fig. 1, p. 23, and he is told at what time they will be ready for him. At the appointed hour he attends the testing shop and identifies his own pieces by his mark, sees them duly measured up and prepared, and the attendants place them in the

machine and break them, himself reading off the record. There will be no difficulty in this, the actual load put upon the test-piece, irrespective of its size or area, always being given. The attendants will then measure off the elongation as found by the actual stretch between the two marks mentioned on p. 23, and the contraction in area at the point of fracture. The inspector will closely follow or personally check this, and the figures obtained must be reduced to tons per square inch and percentages of elongation and contraction. The test certificates will be filled in as each piece is broken, until the whole are done, when the inspector is able to sign the sheets and forward them to his principals. It is seldom, indeed, that a test-piece fails to come up to standard; should one do so, and the rest of the same heat or cast be satisfactory, there will generally be some evident reason. Should suspicion be felt, or more than one piece behave in the same manner, a fresh batch of pieces should be selected and the results again carefully noted. Should they confirm the first suspicions, then the whole of the material from the heat to which they belong should be rejected; but should they come out all right, it may be taken there was some error in the first tests made. The importance of identifying the material from each heat is thus evidenced; as if there was no such means of selection, either every separate bar from the bulk would have to be tested or the whole condemned. By means of his list of materials ordered, the inspector will be able to see that all the steel required is duly rolled, and that he has had proper representative tests from same. Material is not usually allowed to leave the mills until the inspector has approved of it; as when once despatched, their responsibility in the matter ends. They will not recognise further tests, or entertain any questions raised afterwards. The inspector must therefore personally see each bar or plate to the order, and carefully examine it for flaws, laminations, blisters, and other defects, stamping each with his private mark for after-identification, if he so desires.

The work at the mills is more the proving of facts than the exercising of discretion and judgment, and in that sense is more mechanical than what follows at the girder yard. The more acquainted a man is with his work, and the more used to it, the better and more certainly will he perform it, whilst his evident knowledge of what he is doing will stand him in good stead with the testing staff; still the work, unless in a foreign country and for an order of magnitude rendering it necessary that the whole manufacture should be watched throughout, cannot be justly classed as being of that high order alluded to previously. It should, however, if possible, be performed by the same man to whom the after-duties are entrusted, so that the advantage of knowing the whole business throughout should be his.

In previous chapters different questions as to manufacture and methods have been fully gone into, and there is no need to go over the same ground here; whatever is not therefore fully explained in this chapter with regard to inspection in the yard will be found elsewhere.

If the job be a small one with a not very onerous specification, it will now suffice if the inspector pays a visit to the girder yard and sees that they have

the identical material he has passed. At the same time he should have an eye as to the facilities for work, and if a thoroughly practical man he will be able to judge pretty correctly the style and methods of manufacture in vogue. Presuming he is satisfied as to things, he need not again attend until the work is well under way, when, on hearing from the firm, he should proceed to verify the attention paid to specification requirements. Questions as to drilling or punching, planing, fitting, and other items can be checked, and he can assure himself as to the genuineness of the work. Another visit must be paid when the completed work is ready, and he must now go carefully over everything, preferably personally checking all dimensions and sizes, seeing that the right materials have been used, that the workmanship is equal to requirements, and that it is in every way what his employer is requiring.

Should the work be rather more important, a weekly or fortnightly visit during its progress may be advisable, when all questions cropping up can be dealt with and the gradual building up of the girders or parts properly and intelligently followed. During such visits hidden work, or parts which cannot be got at when completion is arrived at, should be examined and passed; and should there be any particular process or stage which it would be desirable for the inspector to personally watch, such can be arranged to take place at any prearranged visit or time.

Work of the first magnitude will require the inspector to be at the yard every day. There will be much work in progress at the same time and at very different stages, and he will need a good memory, a receptive mind, and an elasticity of disposition to accommodate himself to the demands upon his time and attention. Naturally the precise character of his work, or rather its onerousness, will depend largely on the specification. If it is directed that certain things be only done in his presence, and if he also needs to obtain ocular proof of the methods and workmanship at every stage, his hands will be very full, and he will need to be better than the average to avoid falling foul of some one or other of the different foremen engaged. This latter is a calamity he must always study to avoid; an injured foreman can give an inspector double work and trouble, and promote a feeling of uneasiness as to all his work which will be far from pleasant.

Without interfering with the various routine methods of an establishment, *e.g.*, whether wood templating is used or the older sheet-iron method, etc., the inspector is entitled to assure himself that the workmanship at every stage is of that degree of accuracy deemed essential to the final satisfactory assembling of the structure. For instance, no obstacle will be put in his way if he wishes to check the accuracy of the templates when made, or the truth of the planed surface of an expansion bearing. A good man will not go about with his hands in his coat-pockets, but will be alive and actively ascertaining for himself. The manufacturer will generally accord an inspector as much help and as many hands as he wants within reason—some foremen will be only too glad to have their own men manipulate gauges and instruments to save the inspector from bending his back. Help of this character is not desirable—the

man who thinks of his back and his dignity before his work is best out of his berth. At the same time, continual interference or the exercise of his powers more often than is necessary or advisable will be most certainly resented, and he should refrain from doing or seeing anything from mere curiosity or the wish to display his knowledge or authority. What to do and when to do and how to do it, also what not to do, need much tact and knowledge; and herein will lie most of the proof of an inspector's capacity and fitness for his work.

Assume, for the sake of illustration, that the work in hand is a large swing-bridge for heavy traffic, spanning two openings of about 120 ft., and having an overall length of about 320 ft., to be turned hydraulically. A thoroughly good man in every sense will have to be put in charge of this—if he is to be of any use—and he will have to give his whole time to it; at all events, from the period when assembling commences. There will be here girder work, cast-steel work, cast-iron work, forgings of all descriptions, bronze and steel gears, shafting, and much fitting and turning, etc. A mere knowledge of constructional steelwork will hardly suffice. The hydraulic machinery may also be included—as some yards in this country are capable of doing the whole—or again, it may be supplied by hydraulic specialists.

A good man will now have work after his own heart. He will have to be master of all trades, able to follow every operation, and personally familiar with the methods used. His first business will be to test the steel at the mills as already detailed, and, this through, to watch the setting out. He should not interfere here unless it is obvious that mistakes are being made and in order to assure himself as to sizes and dimensions, etc.; a foreman who has made swing-bridges all his life will not be grateful for suggestions as a rule. Let him go a longer way round if he wishes—probably he knows his men and tools better than a stranger could, anyway no good will be done by interference. At the same time, should it be seen that mistakes are happening, a timely word by the inspector will do good. Of course, he has no need to say anything; he can wait until the matter is put before him and then condemn it, but by doing so he is not serving his own employer—for delays are never appreciated—and he is also making enemies in the works for which he will pay at some time or other. It will be impossible to hide from these men that he did not know what was coming forward. It is simply a case of doing *right* on the inspector's part.

He will now have to test the cast-iron bars and, if able, watch the casting of the metal. He should always see his bars run, so that he may be sure they are of the same metal as the castings. His private stamp should be impressed in the mould, so that he can identify them when they are ready for testing. It is a good plan to see the moulds before the castings are run, and to look at the whole disposition of the tackle, especially if any large weights are involved. To a practical moulder all these things enable him to forecast events, and he is better able to inspect the castings when made, as he will know in what direction to look for trouble through any faults he may

have observed. When testing his bars, let him be particular as to the total weights put on, and also let him read the deflection gauge himself. Due note should be taken of all data gained, and every fracture should be seen. If a bar breaks under the test-load, the fracture may possibly show a flaw of some nature; should the others break up to standard no notice need be taken. If, however, the bars as a whole do not come up to test, and there is no explanation of same except bad metal, the inspector has no option but to condemn the castings represented. Test-bars must be run whenever any pieces belonging to the bridge are being cast.

After fettling, and always before painting or oiling, the inspector must carefully go over the castings, ringing them well with the hammer to prove soundness. The large pieces must be carefully checked for winding and size. It will save much subsequent trouble if this is done now, as if they once get in the shop and have had labour on them, and some parts then fail to hold up, it requires much resolution to reject them. Many foremen will start machining even though their setting-out has shown there will be one or two tight places, trusting to being able to persuade the inspector to take them. It often happens in castings of this nature that loose flanges on patterns have got rammed in or out of truth, and in order to make the casting hold up to finished sizes, one flange has got to be only just scraped, whilst the opposite one will want both planing allowances taken off, thus reducing its metal below that specified. It is therefore economy of both time and temper either to personally try the castings over, or arrange to see the setting-out before tooling commences.

One of the chief points to look to in castings is that there are correct dimensions everywhere; thicknesses of metals should always be tried. Wherever there has been a core larger than a bolt-hole it should be ascertained whether the metal is properly distributed or not, as cores are so apt to rise or otherwise get misplaced. If there exists no other way of finding this out, small $\frac{1}{8}$-in. holes should be drilled in sufficient places to prove one way or the other. If a column or hollow strut is being examined three holes will suffice, one in the centre of the shaft and one at either end. By taking the outer diameter and using a piece of wire pushed through the hole until it reaches the opposite side, the thickness of the one wall is readily determined. If the end of the wire is turned at right angles and pushed through the hole until the turned end can be caught on the inside and a measurement taken, this wall also is known. A special kind of caliper is made for testing hollow castings, and for much work is a great convenience, as it dispenses with the necessity for drillings. It is illustrated in fig. 31, and it will be seen that it is only necessary to read off the thicknesses on the scale. Where there are very wide flanges it cannot, of course, be employed, but for many things it has great advantages.

The skin is always to be looked to. For castings in a prominent place this must be specially good, and all corners must be sharp and all mouldings true and free from faults. The texture of the skin tells much to the practical

man, but its chief message lies in the evidence it affords as to the state of the metal when the casting was run. If from very hot metal, it will be very slightly rough, due to the blacking or plumbago being eaten away, but of a bluish tinge. If of cold metal, it will be quite smooth, perhaps shiny and of a good grey colour. The precise shade and appearance will differ according to the thickness of the part and to the mixture used, but these are broadly the distinctive signs to be noticed. The error is nearly always on the "cold" side. Moulders are notoriously afraid of hot metal. It runs so much faster than when colder, and gases are generated so quickly, that the mould is much more severely tried. So the ladles are kept standing until the metal reaches that heat below which they dare not run it, and then the mould is poured. Frequently they wait too long, and then the iron does not reach the far corners, or cold laps are the result. More wasters are made from this cause than from all others combined. It is evident that thick

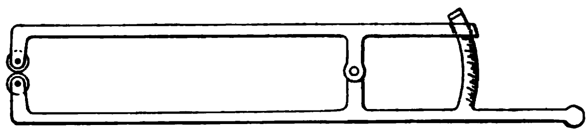


FIG. 31.—Caliper for hollow castings.

castings can be run with safety at a much lower heat than thin ones, and it needs very nice judgment indeed to determine the precise heat for any particular thickness or casting.

According to the state of the skin, then, different likely faults are sought for. If cold run, cold laps are expected; perhaps a riser has not lifted and so a lot of dirt may be on the top side, or a far-away flange has a corner or two short. If hot run, there may be a big "flash" at the joints; the boxes may have started a little, making a wide, unsightly joint; the runners may have drawn a little, or there may be a "scab" or two to be seen. Few inspectors understand the real significance of "scab"; to them it is an unsightly excrescence, which, if cut away, will always show where it has been, and the question which troubles them is whether they ought to allow it to be cut away or be condemned for the ugliness of it. The matter is really much more serious. A scab is caused by a fall of sand in the mould, which may be due to many causes, and the scab itself is merely the iron occupying the vacant space thus caused. Now, if sand has fallen it must have gone somewhere, and the problem is, is it in some part of the casting or has it been rushed through the riser? A very careful search must be made for it, the experienced man knowing the most likely places for it to lodge in any given casting. If good scrutiny and tapping with a sharp-pointed hammer fail to locate in, it may be in the riser; but all the vital parts of the casting should be as thoroughly examined as possible. A scab from the core is the most difficult thing to deal with, in the sense that it is so seldom that the cored part can be really got at to see whether it is clear from them. A

point should always be made of looking at it, if possible, and, if not, then all the upper surfaces in the top part must be thoroughly searched to see whether there is any trace of one. Spongy places are almost always due to a fall in the mould, and should be thoroughly explored with the hammer to ascertain their extent. If in a vital part they are beyond remedy; if out of the way and not large enough to matter they may be stopped; it is best to be very careful with regard to them, because they have no business there, and the inspector is under no obligation to pass them; at the same time they are necessary evils of moulding, and it does not evidence much common sense to condemn castings for faults so small that they can never possibly matter. If any attempt at tinkering or stopping anything, whether sponge, air-pockets, or cold laps, has been made, that particular casting should be subjected to the most severe examination; indeed, some men go so far as to refuse to even entertain its acceptance, and if the practice has been resorted to against their orders they are quite justified in so doing. Often the management knows nothing of such attempts; no moulder cares to make wasters, and they sometimes visit the fettling bank and try to make good anything they may notice. If a flange is short-run, or there be some other similar defect, the moulder will probably wish to "burn" a piece on. This is done by burying the surrounding parts in sand and only leaving exposed the portion it is desired to alter. A dry-sand mould of the missing portion is made and placed in position, and a runner and outlet so formed that metal can be poured in and run over the exposed portion of the casting until this piece has attained melting-point, when the outlet is stopped and the new mould allowed to fill. If well done the job is a good one and may be relied on; but since so much depends on judgment, it not infrequently happens that the time is wasted. The metal which is run off is led into "pigs" and remelted, so that there is not much waste.

Joints should always be particularly looked to. Occasionally the top part gets twisted on the bottom part (the moulding-boxes), and bad and uneven joints result. If much chipping is required to straighten matters, things look suspicious and special notice should be taken. Runners and risers must not be broken into the casting; this is due to the moulder's carelessness in not forming them properly. They should always be cut off bright and sound and be thoroughly solid; if dirty, or showing signs of being "drawn," suspicion as to the soundness of the casting is created. Swellings and lumps should not be present anywhere; they denote uneven ramming by the moulder, and are caused by the sand in the mould not being of the same degree of density everywhere. Rough pitted surfaces are caused by the use of poor facing sand or inferior blacking or plumbago. Deep flanges are often ragged and irregular through the patterns giving poor "draws" and mending having to take place at awkward depths. Loose sand may also get overlooked in such places, and occasionally even tools have been forgotten and left in! In fact, the chances of things going wrong in moulding and wasters resulting are, perhaps, greater than in any other trade. It is

doubtful whether any work yet written on the subject has dealt or could deal exhaustively with its craftsmanship. Moulding is to most engineers the most attractive subject, because of its risks and uncertainties and the necessity there is to be always on the *qui vive*. Thoroughly good moulders are scarce and are seldom wanting jobs. In the short space possible to be devoted to consideration of the art here, it is not practicable to pretend to do more than mention the chief points to be noted by the inspector when called upon to exercise his judgment on castings brought before him. What has been said will, however, prove to some extent that examining them is no child's play, since the fruits of much experience must be brought to bear.

It is the casting which is hardly bad enough for the management to consign without question to the scrap-heap which gives an inspector the most trouble. Every man appreciates frankness, but much perturbation is often caused when the manager draws an inspector's attention to some defects which he says he thinks are hardly serious enough to form fair ground for condemnation, and asks that it may be accepted. Probably it may be a dry-sand casting for the swing-bridge and weigh several tons, and may have cost weeks of work to get ready, so that it represents a value of, perhaps, a hundred pounds or so. Now is needed great independence of character on the part of the inspector, and he will need all his firmness not to be influenced by the manager's persuasions. It is, however, imperative that he face the question calmly, remembering for whom he is acting, and that no personal considerations of any nature be allowed to interfere with his judgment. The casting is for a certain purpose; are its defects such as to militate against the proper accomplishment of that purpose, and will they in any way detract from its value as a constructive agent? These are the questions he has to answer, and he must have his employer's opinions always before him. If no good purpose would be served by the defective parts being other than what they are, the casting may be accepted, since time would be required to replace it. If, however, they constitute any drawback to the proper execution of its functions in its allotted place or tend in any way to weaken it constructively, then it becomes a duty to only accept what was intended when the drawings were made, and nothing short of this will do. The firm took such risks when they gave in their estimates, knowing best what they could and could not do, and the inspector's shoulders were never meant to take over their responsibilities. The inspector's first duty is to his specification and drawings, as representing his employer's instructions.

CHAPTER X.

INSPECTION—II.

THE steel castings required for the bridge will doubtless be obtained from one of the firms making a speciality of this work. These castings differ somewhat from iron ones by reason that the greatest difficulty is found in keeping them homogeneous and free from flaws—the test for strength being of only comparatively secondary importance. In fact it is this drawback—lack of soundness—which has so largely prevented their use until comparatively recently. Up to a few years ago more wasters were made than sound castings, and consequently their cost rendered them almost prohibitive. Even now they cannot be bought at prices which will compare favourably, strength for strength, with cast-iron. Most works producing them affect a good deal of secrecy as to the exact composition and methods used, though it is pretty generally admitted now that soundness can be secured by the addition of silicon and manganese. The proportions of these two elements naturally to a large extent affect the strength in the manner previously noted when dealing with mild steel, the manganese being introduced to counteract the weakening influence of the silicon.

Often steel castings are accepted solely for their soundness; *i.e.*, tests are not specified. Where a test is imposed it is usually a tensile one from a piece taken from the casting, and it should show from 28 to 35 tons per square inch, with an extension of not less than 8 per cent. on 8 ins. If a bending test is also specified, this will be that a sample must bend cold through an angle of not less than 90° before fracture. It is customary to test soundness by well hammering the castings, and by letting them fall somewhat sharply on to a hard surface, though this latter must be done with judgment according to the shape and weight involved. If the tensile test is passed, and the castings ring true with the hammer, there is no great necessity for the dropping test at all. Castings should be annealed before leaving the foundry, as this greatly mitigates the stresses induced by the original casting and cooling and increases ductility.

All flaws should be well investigated, and if in a working part, or where there is likely to be any stress, should not be passed if of any consequence whatever. On account of their price steel castings are not specified where

iron ones would do, and a steel casting with a flaw may be no better than a sound iron one would be. Extra care should therefore be exercised when dealing with these. What has been said about the inspection of cast-iron will largely apply to this metal and need not be again repeated. The hammer should be used much more freely on steel than on iron; of course, it is not possible to use it to any great extent on the latter, but it is a valuable assistant in determining soundness on the former. Great attention should be paid to narrow necks between large bosses or bodies of metal, the arms of wheels, and other comparatively thin places. Very often the subsequent turning or machining in the shops will reveal unexpected cavities, and steel castings should always be purchased conditional on replacement of such defective pieces.

The mild steelwork specification will probably be strict, since there will not be much unnecessary material nor any great margin allowed, and the inspector will most likely be required to watch all the processes of construction. He will not be bothered by questions of the advisability or otherwise of planing and drilling or punching; but will merely have to work to his instructions. It will pay him to watch the template-making on a job of this sort. It will not be quite straightforward, and there will be a lot of connecting plates, brackets, gussets, bracings, and diaphragms which will all depend more or less on each other, and in which an error in one will mean many more probable mistakes. As before noted, he will not interfere with methods of work, except in so far as they may be contrary to his specification. So many inspectors have fads or cranks which they try to force on the manufacturer, honestly believing that their methods are the only ones which will give satisfactory results. A greater mistake than to do this cannot well occur; methods of work (with the exceptions stated) have nothing to do with the inspector—he is only concerned with *results*. These he can condemn if at variance with what they should be, but he must leave the ends used to attain them severely alone. He is, however, for his own protection's sake, justified in taking account of the methods used, especially if he fears the results, as they will guide him so much in looking for the expected errors. Since the correctness or otherwise of the templating ensures the degree of accuracy the finished work will assume, it is always instructive to have regard to it and to duly note any doubtful work seen. It is not unusual to see a lot of drifting done in the awkward places, and as these are just where accuracy should be the highest they should be particularly watched. In such bridges all the important jointing holes of girder to girder and cast or forged work to girder, etc., should be drilled after the work is together, so that there may be no chance of error. If mistakes are made and holes do not coincide, the inspector has choice of two alternatives: either to have them reamed out to a larger size, taking a larger rivet or bolt, or to insist on rectification by fresh material. The first will depend on whether there is material enough to warrant the alteration, and that it would not interfere with anything else, and also that the error can be made thoroughly good this way.

If not, then there will be no alternative, though it needs very good reason to order the second, since it involves so much delay, and possibly more testing and proving of the replacing material.

The assembling of the parts is a time for vigilance and care. If unsound work ever will be attempted it will be now, and it is at these times that the practical man scores most over the non-practical one. The first knows by experience where to look for the probable deviations, since he has been at it before, and the way the work has been tackled will tell him what to expect. Reason should, however, be the guide in all things, and so long as a good sound job is secured and it is not contrary to specification, the inspector should not be awkward. The *way* it is done is nothing; the *end* is the thing.

One of the points about rivet-holes that should be looked to is the fraze which always forms at drilled holes; it is one of the most serious objections to drilling through the solid in a flange. When so many plates are bolted or clamped together and a drill sent through the lot, a fraze forms on each plate; the faster the tool is sent through the steel the greater or stronger the fraze. Some steels seem worse than others, whilst the speed of the tool and the lubricant used all make a difference. It will be pretty clear that if such a fraze exists and is not removed the plates will not lie together properly or closely, and that the rivets even will fail to make a proper job in drawing them together. Whilst this might not mean any great disadvantage structurally, since they would still in a sense be solid, yet it would pave the way for oxidisation when in service, with all its attendant troubles. All frazes should be removed before riveting, and generally, unless the inspector remembers it, the workmen will not remind him.

After assembling comes the riveting. This may be done either by steam, hydraulic, pneumatic, or hand-power, most probably by a combination of the three last, different means being used for the most suitable places. The first named—steam-power—has now almost died out, having, for practical reasons, been superseded by hydraulic and pneumatic methods; whilst hand-riveting is only employed when the others are not possible. The process used will, of course, depend on what the works is laid out for. The inspector is not responsible for this, but he is for the soundness of the resulting riveting.

Now there are one or two points in riveting which are not usually appreciated and whose significance is not generally understood. More often than not it is assumed that the soundness of the work lies in the pressure at which the rivet is driven. This is quite a mistake. If it were so hand-riveting would never be of any use, whilst we know that some of the best work extant was all hand-riveted. On the contrary, it is quite probable that much of the riveting now daily done is being carried on at too high a pressure. It is only the girder yard knows of the number of rivet-heads which fly in the course of a twelvemonth from no visible reason whatever! And it is only girder-yard men who are led to ask how many more are on the verge of flying,

and how many more still have some stress or other on them which is tending to force their heads off. Yet the rivet steel is all proved material.

Take hand-riveting first. This depends for its success almost entirely on the heat at which the rivets are driven. A good riveting gang will send back rivet after rivet unless it is the proper heat—they cannot make a job of anything short of it. The essentials are a fairly hot shank with an end at welding heat. Given these and a smart gang, and handwork will compare favourably for results with any means yet known. The hot shank is needed for drawing the work together as it contracts, and the white-hot end in order to secure a perfect head. When, as formerly with punched work, the rivet had to be upset throughout its length in order to properly fill its holes, it was necessary to have the shank a good forging heat throughout, or else it would have been considerably weakened. The straight shank was supposed to fill thoroughly a hole of perhaps the shape shown in fig. 32, and unless the heat was suitable the punishment would be severe. Now that drilled or

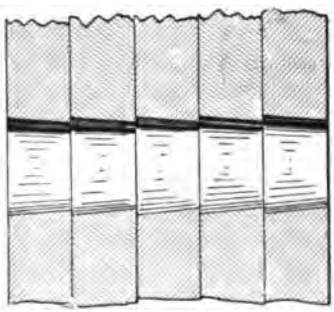


FIG. 32.—Punched rivet-holes.

reamed work is so largely used, a slightly lower heat will do for the shank. The amount of contraction the rivet undergoes just serves to thoroughly pull up the plates, and a very fair job is secured, which does not put any secondary stresses on the rivet.

Turn now to hydraulic work. The characteristic of this method is its immense riveting pressure. Frequently a $\frac{3}{4}$-in. rivet will be driven under a load of 20 tons, whilst larger sizes may have 35 or 40 tons upon them! If, now, the rivets are driven at the same heat as they would be for hand-riveting, what results could reasonably be expected? Through the great power used the plates will be brought far more in contact than any rivet contraction could accomplish, and they will, to all intents and purposes, be solid one with the other. When driven the rivet has still to contract; what will happen then? A tensile stress is bound to be set up in the rivet. Suppose that a rivet 4 in. long in the shank is to be driven and that its temperature is 2000° Fahrenheit. The coefficient of expansion is about ·000011447, and it will therefore have an increased length over its cold state of ·05 in., say $\frac{1}{20}$-in. If the plates are already solid together, what is to become of the $\frac{1}{20}$-in.? Taking the modulus

of elasticity at 12,000 tons, such an elongation would mean a stress of 150 tons per square inch of rivet section, thus showing that the elastic limit would be passed, and that if the head did not fly off the shank would be in a state of permanent set. Of what value will the rivet be under such circumstances? In hand-riveted work the $\frac{1}{20}$-inch would be taken up by the small distances between each plate, since it would take eight to ten plates to make up 4 in., and as no plates are perfectly flat there would be no abnormal stresses developed.

Pneumatic methods are near akin to hand-riveting, and are consequently much less severe on the rivet shank. The plates are not nipped together by any great pressure, and there is therefore room for the rivet to act naturally. At the same time, to produce a good head the rivet-end should be of a welding heat, and the difficulty is to obtain this without also unduly raising the temperature of the shank. The proper method of heating rivets remains yet to be solved. There exists no really efficient means by which the point of a rivet may be made hot whilst the body remains comparatively cool; with existing processes no two points will be alike, nor any two shanks. The consequence is that when the riveting methods demand hot points the shanks vary, and their amount of contraction must vary likewise. If the points are not raised to a sufficiently high temperature to make a good head in the effort to keep the shanks cooler, then the lower pressures of pneumatic systems fail to properly cup and turn them.

One advantage punched holes have for riveting is the latitude they allow the rivet to assume normal conditions as it cools. It is matter of common knowledge that punched work requires longer rivets than drilled—an allowance has to be made for the slight upsetting which takes place in the holes. This varies with the length of "grip" or distance between the heads and the diameter of the rivet; as an example, a 1-in. rivet with a grip of 4 in. would require to be $5\frac{7}{8}$ in. long from the underside of the head to the point end. Since only $1\frac{1}{2}$ in. of length will be taken up by the head, it follows that the allowance made is $\frac{3}{8}$-in. The extra length naturally much modifies the cooling stresses and helps the rivet considerably.

Another point worth noting is that it is difficult to precisely state the stresses the ordinary rivet-head has to carry in everyday work. The vast majority of rivets driven are in either single or double shear, and so long as no bending stresses are set up on the shank the heads play no very active part; their function is to keep the several plates so tightly together that these stresses shall never act. In the great majority of cases they would do this quite as effectively if they were merely cobbled over cold, as there is no great leverage exerted upon them. The matter becomes different, though, where the shank is put in tension through the load taking a direct pull on the heads, or where bending stresses afford an opportunity of a leverage being exerted upon them. It is then necessary to see that the head is perfectly well formed, properly proportioned to the strength of the shank, and thoroughly homogeneous and solid. This can only be secured by forming it at a welding heat.

There are thus two questions raised. What is the proper process to employ and what is the proper heat at which to drive the rivets? It is obvious from what has been said that each known system has advantages, and that these are neutralised to an extent by the rivets themselves. With hydraulic riveting, heads sometimes fly off, and it is difficult to say how many rivets are on the verge of doing similarly. With pneumatic machines rivets are liable to be loose or imperfectly formed. With handwork there is great risk of loose rivets, especially where many thicknesses have to be joined, whilst the cupping tool is very liable to cut into the plate around the heads. With all three methods the risk of burnt heads and shanks is always present. In order to eliminate this last drawback, gas-heating furnaces were introduced, where so many rivets were shovelled into the furnace and lay soaking at a red-hot temperature until they were required. This quite combated the burning evil, but it was directly provocative of "fled" heads, inasmuch us the rivet was the same temperature throughout, and its contraction when driven hydraulically set up the stresses just mentioned. Perfectly formed heads were obtained—the pressures of the hydraulic system would almost suffice to do this on nearly cold rivets—so that the red heat was quite sufficient so far as this goes.

Ideally it appears as though the hydraulic system needed rivets with a cold shank and fairly warm head; the pneumatic with a warm shank and hot head; and the hand with well-heated shank and head. If these could be severally secured, there would be very little to choose between the three methods so far as efficiency goes. Unfortunately there is very little attention paid to the question at all; so long as the rivets go in and are tight under the hammer and the heads look fairly well formed, very little more is ever thought about them. It is now becoming a frequent practice in heating for hydraulic riveting to place the rivets in holes punched through a plate or plates so that just the points protrude and the heat is allowed to play on these. The shanks being covered and protected from the heat, can only get so hot as conduction allows, and this will not be much during the short time it takes to heat the points. If well carried out this arrangement gives very good and satisfactory results, since a good head is assured, whilst contraction does not unduly stress the shanks. For pneumatic work the same method should be followed, except that the holes in the plates would be larger, so that the shanks may get fairly hot; whilst for handwork the old system of heating in a small breeze fire still holds its own. The gas-furnace way of heating is more suited to pneumatic methods than either of the others, and much good work has thus been done with it.

It will appear from the foregoing that even such a simple question as that of heating rivets has many sides and that it is worth the inspector's attention, but more especially so when he has any rivets taking active stresses other than shear. He will be advised in discountenancing heating rivets all over uniformly except for pneumatic methods, and will in all cases look out for loose and defective ones. Burnt, half-cracked, and all imperfectly formed

heads should be condemned and cut out. It should be remembered that machine-driven rivets are never quite so clean as those put in by hand—there is always a trace of fraze upon them. This is no detriment whatever, and in a job of this nature would not be taken notice of. It is only when dealing with very prominent and possibly ornamental work that it is desirable it should be cleaned off.

In examining the forged work the inspector's practical knowledge will be brought much into play. No book can teach the essentials to a good weld or adequately describe the appearance of one. Judgment gleaned from experience is the only guide any man has to help him. All work should be clean—that must always be an essential, and it must be up to size in every direction. With the gears and shafting, he will be called upon to prove truth in all ways, and it will need very careful work to make sure that everything is correct. It will not be enough to inspect the *material* from which the several parts are made; but the fitting and sweet working as a whole, the turning, the general alignment, must all be proved. The inspector should personally know the fit of the keys in the keyways, of the studs in their threads, and of the bosses upon their shafts. He must be able to devise a method suited to the design by which he can prove correct centring, and that, considered as a whole, the structure will work as it should do in position. To attempt to enter into details as to what should and should not be done by him would involve treating practically the whole art of fitting and turning, and this is, of course, foreign to the purpose of this book. Even if that were done, it is doubtful whether it would serve any really good purpose; such knowledge must be acquired by experience. When a man is inspecting or testing anything he cannot be always stopping to think what the textbook said must be done next. He has got to have it all at his finger-ends; it must be second nature to him, or he is morally bound to do more harm than good. It not infrequently happens that another inspector—a man solely used to mechanical work—is sent down to supervise this part, and the two have then to act in conjunction. Such a course has its advantages and its disadvantages. A *competent* inspector will be quite capable of doing the whole thing himself.

When the girder work has been thoroughly overhauled and passed, it must be well cleaned and scraped and have a coat of either oil or paint. Now that it is the practice to work under cover to such a large extent, it is possible to turn out work with comparatively small traces of oxidisation, even though the material has been weeks in hand. Formerly when work was done so much in the open air, it was impossible to prevent plates getting covered with rust, and this constituted a most serious drawback. Many engineers tried to enforce clauses providing that all material should be coated with boiled oil as it came from the rolls, but it was not found practicable. The only way was to insist on oil being put on so soon as the steel arrived at the yard, and this occasioned so much friction that it was preferable to trust to good scraping and cleaning before painting and sending jobs away. At the same time, this is not an ideal way of doing things. Once

material has begun to oxidise no amount of the usual scraping given seems to entirely eliminate it. The bad effects are certainly very much minimised, but that it is not entirely got rid of is proved by the action continuing under the paint when in service, and the necessity of frequent scraping and repainting. The most serious point in the maintenance of mild-steel structures is the annual outlay on paint requisite to keep them in order. The annoying part is undoubtedly that it is not so much that the paint put on is disintegrated by the weather and requires renewing from this cause, but that the enemy to the paint lies under it and works from the inside, forcing it off bodily. A suggestion is here made that united action should be taken to induce the mills to combat the evil. This is actually the only place where immunity can really be secured, and there exists no weighty reason why material should not be coated as it comes from the rolls. It is quite evident that odd demands for the practice cannot be complied with commercially, but if the demand was general, if it was, say, endorsed by the Civil and Mechanical Engineers' Institutes, it would soon be on a very different footing; and since all specifications would call for it, arrangements could be made on a proper scale for meeting it. Experience has proved that an impervious coating must be laid on so soon after rolling as possible, and before the weather has had a chance to act. It is but the other day that some cast-iron water-pipes were taken up which had been down for seven years; they had been coated after casting and before laying with Dr Angus Smith's solution. There were no traces of rust or deterioration visible, even after this long time. This is the sort of thing we want to approximate to with our mild steelwork. It cannot be pretended that Angus Smith's solution would be a suitable coating, nor would a coat of paint be of any use; but first-class results might be obtained if hot boiled oil were put on before the material cooled from the rolls. It would be easy to arrange suitable apparatus for doing this, so that the whole extra cost should not on the average exceed ninepence or one shilling per ton. Bars and all sectional material and also plates, with the exception of their sheared edges, would then have an impervious coating which would be no detriment to future operations, nor indeed exercise any influence upon them, and yet which would effectually prevent the first encroaches of the only real drawback to the much more general use of the metal. The benefit of such a coating would be incalculable, and would be productive of immense savings annually on erected work. Isolated demands for such a precaution will do no good. They only cause friction, because, at present, there are no proper arrangements for meeting them. If the practice was recognised as desirable by the highest authorities and pressure brought to bear in the proper quarters, what is now voted an impossibility and a nuisance, and as being of no benefit when done, would quickly assume tangible form.

This is by the way. To continue with the consideration of present methods, it must be recognised that the covered shop is a great help in the right direction, and that there has been a great stride forward in the state

of work when it leaves the shop. It used to be no uncommon thing for plates and sectional material to lie in the mud in the open yard for weeks, waiting the arrival of a few more pieces before they were put in hand. Perhaps there would be a further exposure to sun and rain of several months before the job was ready for despatch and any attempt at cleaning and painting was made. All this is now very much altered, and it is well it is so. The inspector should see that cleaning and scraping are well done and not shirked, and should pay particular attention to the corners and awkward places. Painters are but human, and like the rest of mankind are ever ready to save themselves trouble.

If the bridge is for export, there will be a vast amount of packing to be done, and this will have to be superintended. All small articles, bolts, rivets, tools, etc., will be boxed in specially made cases. The cantilevers will be taken in parts, and the ends of plates and joints will have to be properly timbered and protected from damage or from doing damage. The specification will contain full directions as to this, and it only remains to add that the inspector should personally check everything over to save trouble at the other end.

The bridge is now ready for sending away, and it may happen that it is stipulated that the actual weighed weights of everything should be secured, and that the inspector should certify as to these. This is always a tedious operation, but it involves nothing more than ordinary clerking, except that precautions should be taken to see that fair weights are given and that the machines are properly manipulated. It is often looked upon as rather a good joke to make them show more than they should do for the time being, and it is well to be aware of this.

From the foregoing it might perhaps be thought that the inspector was nearly always in the unenviable position of trying to circumvent the wiles and tricks of the manufacturer. This is not intended to be conveyed, nor would it be correct, since it is seldom that the management of a place lends itself to petty tricks of any nature. As a class, makers are honourable men and have attained their positions by fair dealing and good work. But when endeavouring to outline an inspector's duties, it is but right to point out where he should pay special attention and the reason, and this naturally involves assuming for the moment that trickery may be attempted. It is very seldom indeed that any real case of knavery is come across. Makers have reputations to keep up, and for their own sakes are careful what they do. Still, no man would be doing his duty to his principal if he did not personally investigate everything he is placed in charge of, and so the inspector should be as careful as though he were buying everything for himself. Let him do his duty and leave the manufacturer to do his.

The keynote to successful inspectorship may be said to be "courtesy." More hangs on the personality of the man chosen than is generally supposed. Whilst thorough mastery of his work is an essential to success, yet if this is accompanied by surliness or a repellent or bombastical manner, much

friction is bound to arise. A good many men go to the other extreme and are "hail fellow, well met" with foremen and managers. This is not required; neither is it advisable to be lavish in either the giving or taking of hospitality. It needs more than the average balance not to be affected to some extent by personal friendship or the sense of obligation, and yet any such bias spells ruin to independent judgment. Not that an inspector should never have friends; but it will be better for him if he does not get on an intimate footing with the men with whom he has to deal. Looked at in a personal light, no man would choose as his buying agent another who was known to be intimate with the seller. Not that he would care to put suspicion into words—he might not have any real suspicion at all; but he would naturally rather have someone perfectly independent to represent him. Let the little courtesies of everyday life pass freely—some men set much store upon them; there is no need to be suspicious of every advance, or to rigidly refuse to take advantage of proffered kindlinesses. Yet let a middle course be steered, and be most careful not to enter upon any obligation which may afterwards have to be paid for. An independent attitude must be studiously preserved, or all freedom of action will quickly be gone.

CHAPTER XI.

ESTIMATING.

This chapter is not intended to be a complete exposition of the intricacies of estimating costs from the works point of view: that is a large question, involving very many issues, which could only be dealt with properly in a special treatise; but it seems proper to give here a summary of the methods usually adopted in compiling estimates, so that the engineer and designer may become acquainted with their principles and be enabled to more certainly construct their own preliminary estimates of work required.

One of the simplest ways of arriving at the cost of anything is to analyse its several parts and estimate the worth of each, the total giving the end sought. Everyone is more or less familiar with this method—it is one which readily suggests itself to even those not accustomed to probe costs at all. It will therefore be as well to follow it here.

As convenient units on which to base figures, the system of estimating at per ton or per cwt. has no rival. All manufacturers reckon their prices this way, and what is done in the shops cannot be very far wrong; at all events, if the same routine is followed, the results should fairly agree, and this is what the designer will particularly wish for. To an extent the use of the ton is misleading, in that it does not indicate where differences in prices really occur. For instance, two men design a warehouse with steel framing for identical objects. The one buys his steelwork at £12 per ton, the other at £14 per ton. It is quite likely that neither knows or could say why the two costs should be so different, and in estimating themselves they might hit on £11 or £13 or any other figure as being a fair price for either. It may be said that this is due to difference in design, or to a lack of knowledge of practical affairs, with perfect truth; but such statements do not help—they define nothing and explain nothing. Why should a difference in design mean so much? Steelwork prices are often as high as £30 and £40 per ton, and again as low as £8 or £10 per ton; yet to the casual observer both are steelwork and nothing more. It is not fair to estimate some work on the tonnage basis; a pair of wrought-iron, highly-ornamented gates or grille would not show up very favourably reckoned at so much per ton or cwt. It

is the workmanship—the labour—which really regulates costs, and it is this factor which is so difficult to understand.

Reckoning on a tonnage base is a fair method so long as the charges for labour are less than the cost of the material. When this is reversed, the costs seem to mount so highly that the sense of proportion is lost, and prices can only be understood when put at so much the piece. We are, of course, now dealing with the former, and wish to indicate in what way an approximately close price can be arrived at for ordinary work.

The manufacturer has to face the following items before he can begin to see any profit for himself:—

(1) The cost of the materials.
(2) The cost of the labour thereon.
(3) The dead or standing charges of his establishment.
(4) Painting.
(5) Packing, carting, and loading.
(6) Railway delivery charges.
(7) Erection expenses.

Now, of these the engineer can generally obtain fairly accurate notions as to 1, 3, 4, 5, and 6; he will be bound to be in the dark as regards 2 and 7; in fact, he will perhaps seldom be able to accurately foretell their amount unless he has had a thoroughly good works training; even then he may be out considerably on some work, since it is notorious how much the prices of different firms sometimes vary for the same work.

(1) The current prices for materials are to be obtained with a fair degree of accuracy from most of the engineering papers, and it will be sufficiently near if these are taken as given. Generally mild-steel sections can be bought at from £6 to £7 per ton; they have been both cheaper and dearer, but in ordinary times when trade is an average, and there is neither boom nor depression, prices will be found to fall between these figures. A good deal will depend on the kind of material required. For instance, if a job consists mainly of angles, it can be bought cheaper than if it was of tees. To give an idea of the relative values of different material, the following were the quoted rates for a given date:—Plates, £6; angles, £5, 15s.; flats, £6, 2s. 6d.; channels and tees, £6, 5s.; rounds, £6, 2s. 6d. per ton. There will usually be about the same differences, the price of plates being the ruling factor. When the manufacturer makes up his costs of materials he must, of course, take so many tons of each and average the results. It is important here to remember what has been previously said about the choice of sections. Prices such as these named are only for material for which there is a good average demand, and for which a fair specification can be given. If one or two bars of a sort only are wanted, it must not be expected that they will be bought at the same rate as an order for 20 or 30 tons would be, and therefore due allowance would have to be made in such a case

also. If the designer sets out to include all the out-of-the-way sections he can find catalogued, and to make as many different ones as possible, and then writes up a specification differing from the ordinary, he must not be surprised if he gets told that his material will cost nearer £10 per ton. If market prices are wanted, market conditions must be conformed to. Add to the buying price 5 per cent. to cover waste of material, etc.

(3) Dead or standing charges are those expenses which cannot be directly charged and apportioned to any particular job, but are common to all the work made. Thus when it takes a workman three days to do any given piece of work, it is easy to say that the labour cost is so much, but it is not so easy to say what the cost of the foreman's time would be upon it, and this would be termed a dead or standing charge. Such items as staff salaries and expenses, coal, lighting, water, rates, insurance, rent, stores, depreciation of tools and plant, etc., are all included under this heading, and it is evident that locality and turnover will largely affect them. The same sized staff may be dealing in one works with double the turnover of another, and it looks therefore as though this charge would be a very uncertain one. So it is in a sense. Some places reckon that their establishment charges average 50 per cent. of their wages costs, others take 100 per cent., whilst nearly every figure between these two is used by some place or another. A works that is near coal may have high rates and dear water; another which has light rates may have heavy lighting and coal bills; again, a place that is well situated for the majority may have a high carriage rate and thus be forced to pay dearly for materials. In well-managed places there is a law of averages which brings them pretty much to the same point when everything is reckoned. A place with cheap labour will have dear coals and *vice versâ*. A fair standing or establishment charge for yards doing a turnover in the cheaper forms of steelwork, such as plain bridge or architects' structural steel, with a total cost of up to, say, £14 per ton, would be 80 per cent. of the wages costs; whilst for works dealing with the higher-priced work, light long-span bridges, swing, tilting, and other more expensive designs, 100 per cent. would be a nearer figure. It is, after all, a very rough-and-ready way of reckoning to charge a percentage on wages costs, since certain yards might very well be doing some common joistwork in one corner on which the percentage would not be more than 25, whilst in another part an elaborate structure might be costing 125 per cent.; yet, for the purpose of the engineer preparing estimates, it will answer fairly well, and has the advantage of simplicity.

(4) Painting, since the requirements of no two specifications are alike, is always considered as a separate item, and it is charged at so much per coat. Thus the man who wants four coats pays four times as much as the man who is satisfied with one. The amount put down varies from one shilling to half a crown per ton per coat. If all the painting is to be done before erection, a fair figure will be eighteenpence per ton per coat; for those coats required after erection, half a crown per ton will not be too much.

(5) Packing, carting, and loading, etc., are again very liable to vary. On some contracts they will be practically nothing for home goods, but will be fairly expensive for export. If the place of delivery is in this country and there is nothing to be done but load on to trucks and dispatch, one shilling per ton will be sufficient; if, however, extensive and careful packing has to be made for shipment, the cost might very well be five shillings, and on bolts and small stuff as much as fifteen shillings per ton.

(6) Railway charges will be entirely dependent on how far the place of production is from the place of erection. If the source of supply is the Midlands and the place of consumption London, about twelve shillings and sixpence per ton will go in this. It amounts to practically the same thing if the work was made in London, since there would be the added carriage on the raw sectional materials. On the other hand, if delivery was to take place at, say, a south-coast watering-place, there might have to be included something like twenty-two to twenty-five shillings. The best means of arriving at a figure would be to take the distance of one of the likely competitors, and either get a railway quotation or reckon it a penny per mile per ton if carried on the midland or northern lines, and three halfpence if carried on southern lines. The only difficulty is that where there is competition for carriage much lower rates can be obtained than where a single company has a monopoly. It is always safer, therefore, to ascertain the rates for a given journey. There will be a variation as to the amounts to be carried; 4-ton lots go cheaper than 2-ton, and quantities of, say, 1000 tons can generally obtain special quotations.

The foregoing are the items which can usually be set down with a fair amount of accuracy by those not in the trade. There is no great technical skill required in their compilation; common sense is the principal ingredient wanted. With Nos. 2 and 7, however, something besides this is necessary; there must be accurate knowledge of the works and of the value of labour, and it is just this which cannot be imparted by any book. The only real guide the non-practical man can have is the memory of past experiences and prices and an attempted comparison between then and now. He cannot give any indication of the probable cost of any work he has not seen before.

The price of labour must, of course, be directly dependent upon the amount of work required to be done, and as the relative cost of a design is determined by its labour cost, it follows that the labour requirements of the designer are the greatest factor in settling prices. If, then, the lowest possible amount is desired to be paid, or a moderate sum for a moderate amount of work, what has been previously said on the economics of design must be very thoroughly digested, and the engineer must make up his mind to curb his fancy by the pockets of his client, and study to moderate his demands in both drawings and specification. Let us look at one or two points which will further illustrate this.

No two works will put down their labour charges at quite the same figure.

For one thing, they will vary according to facilities, and for another it would be strange if so many men were found to hit on the same amount at the same time. Still, there is a certain resemblance, and what one place loses on one point it will gain in another, so that whatever figures may be given here, whilst they may not exactly suit a given yard, will yet be a very fair average of general results and experience.

Ordinary riveted plate floor girders for warehouse work in ordinary lengths, and with well-arranged riveting and details, averaging, say, 35 cwts. to 2 tons each, will cost, punched, £1, 5s. per ton; punched and reamed, £1, 12s. 6d. per ton; and drilled from the solid, £2 per ton for labour only. This will indicate what the specification can do.

The same girders with badly arranged riveting and details, showing a lot of unnecessary work, and arranged so as to save every ounce of weight without regard to work and trouble, will respectively average £1, 12s. 6d., £2, and £2, 7s. 6d. per ton for labour only. This will indicate what the drawings can do. It will be plain, then, that there is a good deal in the assertion that to the designer is chargeable the reproach that British steelwork is the dearest in the world.

Now, if we analyse the labour cost of anything, we find that it resolves itself into the rate at which men can work; and in trying to figure out the probable expense of anything, the only way is to take it in detail, and consider how long each element would take to make in labour. For instance, the manufacturer has men working for him at so much per hour; how many hours will it take one man or so many men to punch the holes in a given flange? The rate the machine will work at is known; the comparative skill of the men is known; judicious comparisons and a little arithmetic will elucidate the probable time it will take; the time multiplied by the rate yields the cost—the result being that for one element in the flange the money value is calculated. The planing, the straightening, the assembling, the riveting can all be treated in the same way; and similarly for every part of the girder until the total value is reached. In this way would the estimate for labour be got out for entirely new work, and the truth of it would be in direct proportion to the power of the estimator to enter so thoroughly into it as to be able to forecast the hours which would have to be worked to accomplish each little part.

Now, none but a specialist in steelwork could possibly do this, and so the method is of no use to the designer. He needs figures he can use without having to enter so thoroughly and minutely into their derivation. It is very difficult indeed to indicate such as shall be fairly true, and yet broad enough to be used for his work. Practically, he must be given a series of representative figures, which he will have to use his judgment in applying. At best this will be a makeshift, but it will be better than not knowing whether work of a certain type is worth five shillings or five pounds per ton. The best way for anyone who wishes to be able to arrive at fair prices with some show of accuracy will be to dissect all estimates which come his way, deducting items

1, 3, 4, 5, and 6, thus leaving a probable figure for 2 in the case of delivered only work, or 2 and 7 for delivered and erected. The exercise would be most instructive, and the figures obtained would then be compared with those here given.

Freak figures are not desired. They would not help in any way, but would only confuse the real issues. It is not likely either that different firms would recognise the same figures as being applicable; methods of costing, hours of labour, situation of works, routine, management—all have their direct bearing on them, and consequently a variation of a few shillings per ton for different yards is to be expected. At the same time, any differences will be within this margin, and so the figures given will be quite accurate enough for the purpose required. Fair average values may then be taken as follows:—

		Per ton. £	s.	d.
For structural steelwork in buildings, punched work.	For rolled steel joists, holed and cleated, with template cut ends,	0	7	6
	„ compound girders and joist and plate stanchions, perfectly plain,	0	15	0
	„ compound girders and joist and plate stanchions, bracketed and prepared for connections,	0	18	0
	„ compound girders and joist and plate stanchions over 25 ft. in length,	1	0	0
	„ plain plate girders averaging 2 tons in weight and under 35 ft. long,	1	5	0
	„ plain plate girders over 2 tons in weight and over 35 ft. long,	1	10	0
	„ fish-bellied or rounded ends 2 tons in weight and over 35 ft. long,	2	0	0
	„ built-up stanchions of good section and under 2 tons per piece or length,	1	15	0
	„ heavy stanchions of good section and over 2 tons per piece or length,	1	10	0
	„ heavy box-plate girders, 10 tons and over in weight,	1	10	0
For railway and road bridges, punched and reamed.	„ plain bridgework, plate girders, square spans up to 40 ft.	2	0	0
	„ „ „ „ over „	1	15	0
	„ „ „ skew spans,	2	5	0
	„ heavy bridgework, plain, good work,	2	2	6
	„ lattice and open-web type bridgework, square spans up to 40 ft.,	2	10	0
	„ lattice and open-web type bridgework, square spans over 40 ft.,	2	7	6
	„ lattice and open-web type bridgework, skew spans,	2	12	6
	„ heavy Linville or Whipple-Murphy trusses, large spans,	2	5	0
	„ light foot-bridges, lattice type of girders and stringers,	3	5	0
	„ pin truss and light bridges of long span,	3	5	0

		Per ton. £ s. d.
For general use.	For plain angle and flat riveted principals up to 30 ft. span, in large quantities, ...	1 5 0
	„ plain angle and flat riveted principals over 30 ft. span, in large quantities, ...	1 7 6
	„ smithed rounds and linked principals up to 30 ft. span, quite plain, in large quantities, . . .	2 10 0
	„ smithed rounds and linked principals over 30 ft. span, quite plain, in large quantities, . . .	2 15 0
	„ light complicated roofs, plain, but much work, . .	3 15 0
	„ „ „ all smithed connections, but much work, ...	5 0 0
	„ light complicated roofs, in small quantities, . .	7 0 0

The above list will cover the greater part of the steelwork annually made, and is intended for *quantities*. Single girders or pieces will come at a higher rate. Except where otherwise mentioned plain work only is understood; the "refinements" mentioned in Chapter VIII. will cost more; in fact, it is possible by virtue of specification and drawings to put anything up to £2 per ton above the rates given on even perfectly plain work. Steelwork is not infrequently let in small quantities at £40 to £50 per ton; yet since the material will not vary so very much, nor any of the other regular charges, it does not take much arithmetic to find what is left for workmanship and profit. In the table the items under steelwork for buildings are for punched work; all the rest are for punched and reamed—the usually accepted conditions for both.

With these rates before him the designer should not get far wrong in his preliminary estimates. Care will have to be exercised in selecting for any particular job, and especially must it be borne in mind that any unnecessary work will send the amounts up very considerably. It would be possible to give prices for much miscellaneous work, but as they would not in any sense be representative, they would serve no purpose but that of confusing the user and are therefore omitted. It will be better, when estimating for anything not in the list, to take it part by part and so price it, this analysis serving, when collated, to determine the final price.

As yet the question of profit is untouched. It is a very difficult one to allocate, and whatever is said thereon is bound to be the means of exciting unfavourable comments. Most men believe in making as large profits as possible; others are content to keep going until time will bring the trade their way. Many years ago huge fortunes were made in bridgework; but times have changed, and many large concerns now find it difficult to pay 5 per cent. regularly. The general practice in the trade is to take a percentage of the total costs, and adding this to them, thus fix their final prices. Some people add as much as they think they can get; others always stick to the one percentage. Of course markets rise and fall, and work which at one time can be bought for £12 per ton might at another time be worth £14. It is certain

that costs could not vary as much as these figures seem to indicate, and that therefore the lower price is a cut into profits. It will only be the maker who will be able to fix prices at the prevailing market rates, and it would be hopeless to expect the engineer to so closely follow these as to be able to say within a little what amount of profit, if any, the competition expected will bear. Very many jobs have to be taken at prices which leave absolutely no margin, in order to keep the shops open and the men together. It is better to keep tools employed than to let them stand; and so long as the maker is not daily sinking money, but just keeping things going in slack times, he will be well content. On the other hand, if through limited competition, or that for certain work he is better placed than others, and so expects to be awarded the contract, he makes such jobs pay a good percentage in order to average a little with the others. This is but human nature, and business as we understand it. When a firm knows its neighbour is in competition with it over work, it considers everything down to the smallest detail; and having a knowledge of the other's plant and facilities, attempts to bring its own prices to a figure which will just barely cut under the other. Close cutting, such as this, is, of course, a benefit to the buyer, since the profit expected may be cut so finely as to be near the vanishing point; whereas, without competition, a good profit percentage would be added, and would have to come out of the purchaser's pocket. This is but one of the elementary principles of keen buying.

Under the circumstances the best way for the engineer will be to take a fair percentage on the estimated costs and add this to them. He will then have a price per ton which he will be reasonably sure will be within probabilities; and if in his buying he can place at less, he will know that the cutting has been keen and be gratified accordingly. Fifteen per cent. is an average amount which would be fair to both buyer and seller, and can be used with confidence for well-bought work.

It is only right to point out that the different classes of work do not usually carry the same percentage. Thus the higher the price the more profit there will usually be in it. In the lower-priced jobs it is weight which tells and the turn over which is the essential. In heavy warehouse and other undertakings, where there may be some thousands of tons of the plainest work, perhaps scores of girders all exactly alike, and heavy units of 10 to 30 tons each, the estimated profits will be cut very low indeed, and 10 per cent. on the tonnage costs would be looked upon as good profit. On such work a medium-sized yard could easily average an output of 100 to 150 tons per week, whereas on bridgework of the ordinary stamp it could not do more than about a third of this. As the profits are per ton, it follows that 5 per cent. on the first is as good as 15 per cent. on the second, and *pro rata*. If, again, more difficult work is in progress—say a swing-bridge or equivalent—the output for the type in tons will be exceedingly small, and a corresponding tonnage profit rate must be made. Many outsiders run away with the notion that if work is paying 10 per cent., this constitutes a handsome return on capital. Far from it in the majority of cases. Most of the yards of this country do

work of all classes, from common joists to intricate girders and roofs; now, if one of them can get a run on cheap work and do the *turnover*, and its profits are 10 per cent. on costs, it may make a return on capital of 10 per cent., or perhaps a little more. But let the run be on bridge and roof work, and the percentage on costs the same, the return on capital will not be 3 per cent.! As an illustration, suppose the capital to be £100,000; the normal turnover of the yard may average 4000 tons at an average price of £12 and a percentage profit on costs of·10 per cent.; the nett profits will amount to £4800 per annum, equivalent to a return on capital of just under 5 per cent. Let there be an exceptionally heavy output of cheap work one year, raising the tonnage to 10,000 tons, and reducing the average price to £10 per ton and percentage to 8 per cent.; now the nett profits will be £8000, showing a return on capital of 8 per cent. Further, let there be another year when work runs all on the light or expensive variety; the tonnage is reduced to 2000, the average price raised to £20 per ton and percentage to 20 per cent; the nett profits will be £8000 again, showing only 8 per cent. Thus the actual profit on the work in hand may easily be out of all proportion to the nett return to owners, and a very low expectant profit on cheap work is more remunerative than a comparatively high one on dear work.

The 15 per cent. mentioned must then be taken to apply to average work selling up to, say, £14 per ton. Above this rate and up to £20 per ton, 20 per cent. should be taken, and above £20 per ton 25 per cent. at least, whilst for cheap joistwork a keen market will often cut down to 10 per cent.

Some of the more conservative and older established firms in the country will not join in this open competitive work and require their names to be paid for. They disdain the cheap trade and abhor joistwork, except as joists may be incorporated in more complicated structures; a compound girder is hardly seen in their yards. These firms take the cream of the *engineering* constructional work—the more complicated roofs, the light long-span bridges, the awkward and difficult jobs which require engineers to carry out and cannot be made with multiple punches and duplicate templates. Huge staffs have to be supported and extra skilful workmen paid, and work is turned out which has not its parallel in any other country of the world. The Americans have not the time either to design or to make it, the Germans have not the money though they might have the wish, the French reserve such work for exhibition only—it is this country alone which delights to produce it and prodigally spend its money. There is great gratification both in its design and execution —of a purely personal nature. At the same time the firms engaged upon it are not philanthropists; they have shareholders and directors to consider, and the ordinary rules of both estimating for and doing work will not apply to them. They take a great pride in their achievements, but their estimated profits on costs may be anything up to 50 or 100 per cent. For reasons already given they seldom pay over 7 or 8 per cent. on capital, and often not anything. Although the estimated profits per ton seem high, yet the vast expenses attendant on same, the long time they are in the shops, and the

small tonnage turnover all contribute to most materially modify profits on capital.

The question of costs of erection is so absolutely dependent on locality that little real guide can be given. Position of work, distance from a railway, local facilities, local labour, surroundings, natural obstacles, traffic difficulties, height above ground-level and the like all have a marked effect on prices. There is not the same control over labour as at the yard, out expenses have to be paid, weather and other trades may be a hindrance, and so it happens that even firms themselves have very little real knowledge as to what it will cost. Every circumstance making both for and against is weighed as carefully as possible; the site is often visited and local information gleaned; if air has to be used because of water, minute inquiries are made as to every item; but the element of chance is so large even when all this is done, that the costs finally put down are always looked upon as more or less tentative. On some work, such as large buildings or warehouses, it has been possible to rather narrow the risks, but on bridge and analogous undertakings there must always be uncertainty. Personal foresight or acumen will help one man to arrive at a more correct figure than another, but this does not remove the calculation from its element of guesswork.

Plain structural steelwork, when there are no hindrances from other trades, strikes, lockouts, weather, etc., can often be erected for about £1 per ton. On the other hand, if the site is awkwardly situated, badly approached or confined, and the steelwork at all difficult to handle, this may be increased to thirty or thirty-five shillings per ton. Bridgework will vary from the plain square-span plate girder type on road levels at thirty shillings per ton, to the light long-span high bridge erected under traffic at perhaps £4 to £5 per ton, or the deeply sunk caisson or cylinder type, where, according to the nature of the ground, costs may be anything from £3 to £10 or £15 per ton, or even more. Generally a railway bridge of moderate span can be put up under traffic for about £3 per ton, though this all depends on the help afforded by the railway company, who may at times so assist as to make £2 per ton a nearer figure. Large bridges may cost more to erect than to make, and it would be folly to attempt to even outline any figures at all. If even with all drawings and the fullest possible particulars available an experienced estimator can but make a guess at prices, it is evident that if any figures were given here they would but be misleading. It must be sufficient to state that erection prices for the ordinary grade of work under ordinary conditions vary from between £1 to £2, 10s. per ton, according to the weight involved and the requirements to be met. A light job in an isolated spot is bound to cost more than a heavier one—perhaps just as difficult—in an accessible spot. It is repair and extension work which is the most costly in erection. All workmanship at site beyond that needed for merely placing pieces in position and fastening up will cost anything over double the rate in the shops. If tools and tackle have to be sent on site, and rivets cut out or cutting or fitting be done, money is very quickly spent; whilst if all that requires doing is merely

lifting into place and bolting up, it is often surprising how little the cost actually works out at.

As an instance of the way this method of estimating works out, let us instance the case of a roof with span of 60 ft. and angle and flat principals. The total weight is 70 tons, and the place of delivery London. It is supposed the work will be made within 120 miles. The specification is reasonable—punched and reamed holes, two coats of paint; the sizes figured are marketable and easily obtained. Figures will be obtained somewhat as under:—

Steel and waste,	£6	2	6
Labour thereon,	1	7	6
Standing charges, 80 per cent.,	1	2	0
Painting,	0	3	0
Packing, carting, etc.,	0	1	0
Railway charges,	0	10	6
Total costs,	£9	6	6
Profit, 15 per cent.,	1	8	0
	£10	14	6

This would probably be called £10, 15s. per ton, f.o.r. London; and if it was expected that a discount of 2½ per cent. would have to be made on payment, this might in cases be further added. If the work had to be erected at, say, a height of 30 ft. above ground-level, and access and all conditions were easy, a further £1, 15s. per ton might be added, made up of £1, 7s. 6d. the expected total costs, and 7s. 6d. extra profit and to cover risks, etc.

If, now, the design for this was of smithed rounds and links, otherwise fairly plain, with the weight and all conditions the same, the labour charges would be about £3 per ton and the standing charges £2, 8s. This would bring the costs up to:—

Steel and waste,	£6	7	6
Labour thereon,	3	0	0
Charges, 80 per cent.,	2	8	0
Painting,	0	3	0
Packing, etc.,	0	1	0
Railway charges,	0	10	6
Total costs,	£12	10	0
Profit, 15 per cent.,	1	17	6
	£14	7	6

It will be seen how rapidly the price mounts when more work than need be for safety and strength is put into steel structures. Where the labour costs

are high, the time spent must be longer, the turnover and tonnage output less, and standing charges and other expenses are bound to follow suit.

Success in estimating from the designer's point of view will lie in ability to make comparisons and a retentive memory. Given these, it will not be difficult, after some experience and study of conditions, to forecast the probable cost of work to the buyer within a reasonable margin—say 10 per cent. At the same time it will be obvious that since the outsider cannot know the prevailing trade outlook so accurately as the manufacturer, it cannot be expected that he will be able to precisely forecast what the latter will charge.

Success in estimating from the manufacturer's standpoint will lie very much in the system of prime costing adopted, and the method used in applying or making use of the results so gained. This ground has been covered by the articles in the *Engineer* on "The Preparation of Estimates," to which the trade reader is referred.

PART II.—PRACTICAL SHOP WORK.

CHAPTER XII.

OFFICE ROUTINE.

In considering the works side of constructional steelwork, it will be necessary to make continual references to what has been said in previous chapters. Neither the works nor the designing engineers possess a monopoly of common-sense observances and maxims, and what is applicable to the consultant is also applicable to the works drawing office, and *vice versâ*. The pity of it is that the theoretical and the practical man do not know more of each other. Were each as conversant with the other's views as they might be, not only would there be very much less friction than is sometimes the case, but the whole home and foreign trade of the country would be immensely benefited. So long as both pull opposite ways, unity of action is morally impossible, and the two forces will each blame the other for what is but the result of their mutual unacquaintance. So that if this section of the book is to be of any help to the manufacturer's draughtsman, it can only be so in conjunction with the preceding chapters.

When drawings enter the works drawing office after a contract has been let and signed, for the purpose of preparation for the yard, in most establishments a certain routine is observed. The advantages of method in dealing with everything are so well known that the passage of a design from the engineer's conceptive drawings to the girder-yard foreman's working details is nearly always by a routine system, which has either been gradually evolved during the growth of the works or adopted from elsewhere. The exact procedure is probably not alike in any two cases—variations will always be made to suit individual preferences or exigencies of special business, and it would be a difficult and, at the same time, a foolish thing to say which system is the best out of the hundreds devised. There cannot be a *best* in that sense; scores are bound to have features of great merit, and to be better in some and worse in other respects than each other. So long as they fulfil what they were intended to in a satisfactory and economical manner, no fault should be found with them. It would be impossible to describe here a number of these systems, or to compare them to any advantage; an attempt will therefore only be made to outline one, which has proved itself exceedingly satisfactory

in working and which is amongst the most economical known. It is not claimed that it is better than the best, but only that there are none better; it will be freely admitted that there are others equally as good and effective.

Whatever the routine adopted, the essentials are that it should be (1) simple, yet of maximum efficiency; (2) economical; (3) expeditious; (4) entail as little work on the department as possible. To this end everything superfluous should be pruned away. It is generally admitted that checks on labour and calculations are necessary; but so long as a proper check is instituted, there is no need to "check this check," and perhaps again recheck, as is the case with some methods. Where such multiplicity of checks has been found necessary in order to eliminate all errors, it is time some of the staff were also eliminated. A very good rule is never to trust to one man's work absolutely, but to give it an independent check; when this has been done, everything needful and advisable has been attended to, and if errors still exist disciplinary measures should be taken. There are works where three and sometimes four men separately go over the same thing —there is nothing economical here. There are usually sadly too many clerks in the drawing office—or juniors who seldom get a chance of being anything else. Clerical work should be reduced to the absolute minimum, compatible with efficiency; draughtsmen have had too expensive an education for such labours. In some offices every job is furnished with numberless sheets of quantities and figures, which none but the skilled therein can decipher, and which have cost untold labour and time. In others the reverse is the case, and drawings are forwarded into the yard with the draughtsman's benison, but bare of any other accompaniment. The one is prodigal of the time of the staff, the other of the time of the foreman and his platers. Both are expensive; but considering how seriously ruinous the latter can be if they misinterpret, perhaps the former is the least evil. There is, though, no necessity for extremes either way; the mean is what is required.

As previously noted, when drawings are received they are seldom in a fit state for the shop, and the first thing to be done is for the chief draughtsman to personally carefully examine them and compare with the specification. Frequently he will find contradictory statements, and these are to be carefully noted, and, if inexplicable, referred to the engineer for settlement. In fact it is always the best and safest plan to draw attention to all such matters, either asking for a decision or stating the course being followed; the designer has then an opportunity of revision. The specification is usually deemed to be of more moment than the drawings, and a detail than a general view; if a large-scale detail is plain and explicit, it will of itself settle any question raised on the smaller-scale portions. There is no need to raise queries unless there is room for evident doubt; it is foolish to fear to trouble when in doubt.

When a general idea has been gained of the drawings and their more obvious defects and deficiencies noted, they should be handed over to a competent man for working lists of materials to be made. These lists serve a

twofold purpose: they indicate to the girder yard the size and dimensions of every piece of material required, however small, together with its position in the job, and they are used to order the steel, etc., from the mills. A working list is of great value in the shops, as it enables the foreman and plater to select the sizes and set aside the right stuff, as also giving them great aid in rapidly following the drawings. To the template shop it is indispensable; without it the template-maker would be unable to always understand what was in the draughtsman's mind when he ordered the steel, and delays would occur and questions have to be answered.

It is usually imperative that the orders for material should be got out with as little delay as possible; and if prices have not previously been obtained, a rough table of sizes and approximate weights should be first drafted and sent in to the order department, so that bottom prices may be assured. Mills do not care to give their best rates unless they have the proposed specification before them, and if there is time it is best to get this out; but with time becoming more and more "the essence of the contract," it is not always practicable to delay until this is done, and in that case as careful an estimate of quantities should be given as can be got out. Some men are very capable at this work, and can rapidly and with a surprising degree of accuracy apportion probable total weights to different sections. The best man for the purpose should always do this, and in medium-sized offices it will be the chief. A good way of getting out the sections is to take foolscap, and as the different sizes are noted put them down along the top of the page, ruling a column to each size. Then take each girder or part separately and jot down its sections in their proper columns; exact lengths or widths will not be necessary so long as a fair estimate is being made. When the job has been thus roughly analysed, the weights should be run out, by adding together all the lengths of any one section and figuring these at the known weight per foot-run. A sheet done in this manner would appear as under:—

2½″ × 2½″ L^{s}.	3″ × 3″ L^{s}.	3½″ × 3½″ L^{s}.	4″ × 4″ L^{s}.	6″ × 6″ L^{s}.	3″ flats.	4″ flats.	6″ flats.	5″ × 2½″ [^{s}.
18/6′ ⅜″	6/20′ ½″	18/18′ ½″	100/5′ ½″	20/40′ ⅝″	120/8′ ⅜″	60/8′ ⅜″	40/5′ ½″	100/6′ ⅜″
28/18′ ⅜″	10/8′ ⅜″	60/10′ ⅜″	3/6′ ½″	60/8′ ⅝″	200/4′ ⅜″	120/10′ ⅜″	20/10′ ½″	5/8′ ⅜″
4/3′ ½″	40/2′ ⅜″	120/1′ ⅜″	6/8′ ½″	80/20′ ⅝″	300/1′ ¼″	4/5′ ½″	40/10′ ½″	10/7′ ⅜″
Etc.	Etc.	Etc.	Etc.	Etc.	Etc.	Etc.	Etc.	Etc.

A man fairly good at mental arithmetic would not trouble to write the numbers down, but would run out the feet-run as he went on; thus the 4 in. × 4 in. L^{s} and the 4-in. flats columns, for instance, would read respectively as:—

500 . .	½″		480 . .	⅜″
18 . .	½″	and	1200 . .	⅜″
48 . .	½″		20 . .	⅜″

Juniors would total the lengths and find the weights as the sheets were filled. By adopting this method a fairly close schedule of quantities can be given to the mills, who would receive it in this form, together with a copy of the test and other applicable clauses from the specification:—

80	tons	$3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$	angles.	Usual lengths.
20	,,	$3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$	,,	,,
140	,,	$4'' \times 4'' \times \frac{1}{2}''$	,,	,,
60	,,	$6'' \times 6'' \times \frac{5}{8}''$	,,	,,
90	,,	$3''$ flats.		,,
40	,,	$4''$,,		,,
		Etc.		Etc.

They will then be able both to give close prices and state dates for deliveries, and it will be understood that the usual extras will be chargeable. It is worth while being at this trouble, as bottom rates will not be given unless something is known of the specification, and of course time deliveries could not be stated.

It is generally found best to purchase through merchants. These firms make contracts with different mills to take so many thousand tons in the twelve months, or for any other stated period, and usually deal with several mills. They therefore possess the advantage of being able to place orders either in part or whole according as to whether the delivery required is urgent or not. All mills are not rolling 4-in. flats or 4-in. × 4-in. angles at the same time, and so it follows that by judicious placing considerable saving of time may result. Merchants enter into their contracts according to their estimate of what they can sell and the probable state of the market during the coming period. They may thus stand either to make or lose money, as they must compete one with the other to an extent. The arrangement suits the mills, since they get a guaranteed output and are relieved of the necessity for seeking sales. Some large bridge yards contract also in this manner, but the average maker buys as he requires from the merchant.

Whilst prices are being settled, the drawing office should be proceeding with the detailed working lists. They should be written first in pencil and then independently checked before being finally adjudged correct. There will, perhaps, be several points about which doubt is felt, and these should be queried and a note made in the margin to the effect that the particular plates or sections were ordered of such and such dimensions, so that the plater may be able to identify the materials. When only just as much steel is being ordered as is necessary for the job, it is plain that if any of it is misappropriated there will be trouble somewhere; if the sizes are made so that they will cut to the longest or largest dimension which might be required, the order can be passed, and if a little has to be cut to waste it will be better than delaying until an open question is settled.

The lists for the shops will be written on ruled "list" paper, which should be a very strong foolscap specially made for hard wear; a good ruling will be as follows:—

Working List of Steel. Order No. 653.

1′ 0″ deep at ends. 1′ 6″ in centre.	For 1.	For 20.	Cross girders, 20′ 0″; Centres of main do., 19′ 10½″ long, 1′ 0″ deep at ends, 1′ 6″ in centre.	
Web plates .	1	20	19′ 10¾″ × 1′ 6¼″ × ⅜″	Ordered rectangular.
Top flange (flat)	1	20	19′ 10¾″ × 10″ × ⅜″	
„ „ „	1	20	10′ 0″ × 10″ × ⅜″	
Bottom „ „	1	20	20′ 3″ × 10″ × ⅜″	Bent
„ „ „	1	20	10′ 3″ × 10″ × ⅜″	„
Etc.	Etc.	Etc.	Etc.	

The heading "Working list," etc., will be in heavy black letters and appear on every sheet; the vertical lines will be faint red, and the horizontal the ordinary blue ruling. The written heading indicates the particular piece or pieces to which the under items belong; the first column contains the location of each several piece of steel, the second the number required for one, the third the total number required for the lot and therefore the quantity ordered, the fourth the finished dimensions, and the fifth any particulars regarding same which are to be noted. It will be seen that the web plate, for instance, is ordered rectangular, whereas it will be of a very different shape; and this shape is shown in the last column as a guide to the plater, who will know that he is expected to have it cut to the proper sizes in the yard. For the same reason the bottom flange plates are shown as having to be bent to figure. With this list to guide him, any workman will be able to at once see which plate or section is intended for any particular position, the size it must be finished to, and also those it should come in at from the mills. When it is ordered of a different size to which it should finish, the fact is noted in the last column and, if necessary, a sketch given. All special notes or explanations advisable will always be found here. Each girder, stanchion, or piece will have its own list of materials, so that when a job is in a hurry several men can be at work simultaneously; it will only be when several pieces are exactly alike that they will be placed together; any variations, such, for instance, as the end cross girders on a skew bridge, which gradually decrease in size, should have separate lists to themselves. Taking an ordinary railway bridge, consisting of two main girders alike, cross girders, rail-bearers, and dished plate flooring, there would be—

(1) A list for the two main girders.
(2) „ all cross girders which are alike.
(3) „ odd cross girders (a list to each).
(4) „ all rail-bearers which are alike.
(5) „ odd rail-bearers (a list to each).
(6) „ flooring.

When the lists have been checked it is the practice in some places to write them in ink over the pencil, letting juniors clean them up for the yard, and in others to make fair copies. Either may be adopted according to the size of the staff, the latter way making the most presentable job; if this is used, the whole of the matter must be checked by two men, the one reading the copy aloud and the other following with the originals. Small yards will only need one copy of the lists, larger ones may want two or perhaps three. No more should be made than is necessary; at the same time the foreman should be consulted, and if a push job is in, and an extra copy will facilitate arrangements, one should be made. Instead of writing all the copies some drawing offices write one on tracing paper and then photo the remainder with the blue process. Each place will adopt the cheapest plan. Occasionally there may be some stock material in the yard which it is desired to use up for packings, etc.; when this is the case the lists should be marked "stock" in the fifth column against the selected items.

The lists made, the "Orders for materials" must be drafted from them. At times this is a tedious operation and is somewhat akin to that of determining the quantities for prices, except that now the exact lengths and sizes will be taken from the working lists. All plates, angles, tees, channels, etc., should be brought together similarly, the numbers for each length being particularly noted until the whole of the material has been collected. Then the ordering list can be written up, all similar sizes and lengths being added together, resulting in sheets approximately as under:—

Order for Material.

40	Plates	35′ 0¼″ × 2′ 0¼″ × ½″
20	"	30′ 0¼″ × 2′ 0¼″ × ½″
15	"	10′ 8¼″ × 2′ 0¼″ × ½″
90	"	30′ 9¼″ × 1′ 10¾″ × ½″
50	"	16′ 6¼″ × 1′ 9¼″ × ⅜″
	Etc.	Etc.
10	Flats	40′ 0″ × 16″ × ½″
20	"	30′ 0″ × 16″ × ⅜″
100	"	25′ 0″ × 12″ × ⅝″
75	"	10′ 0″ × 9″ × ⅜″
	Etc.	Etc.
200	Angles	6″ × 6″ × ⅝″ × 35′ 0″
120	"	6″ × 6″ × ½″ × 20′ 0″
40	"	4″ × 4″ × ½″ × 36′ 6″
20	"	4″ × 4″ × ½″ × 32′ 9″
540	"	4″ × 4″ × ½″ × 7′ 6″
	Etc.	Etc.

Occasionally some of the plates will be known as "sketch" plates; that is, they are required to be sheared to irregular outlines, and of which a

dimensioned sketch is put in the last column. Care has to be exercised so that the cost of thus cutting them will not be more than the loss of the waste if they were sheared to size on arrival at the girder yard. The mills will not object to a reasonable proportion, but it is evident that someone must stand the loss of the waste (the surplus material sheared away), and they cannot be expected to do too much of this. Often the extra cost for sketch plates will be fifteen shillings or £1 per ton, and if it can be so arranged that what has to be cut away can be utilised for packings, angle pieces, or other small odds and ends, it will often pay the girder yard to do its own shearing. If mills know that a large proportion of the plates required are to be thus cut, they will either raise the price all round or specifically charge an extra for them. Consequently the relative costs must be considered before asking the mills to do the shearing. If a lot of corner pieces are required cut at an angle of 45°, two can be placed together and ordered as a rectangular piece, the shearing apart being done on arrival at the yard.

It will be noticed that in the order for plates an odd $\frac{1}{4}$-in. is added to both lengths and widths. This is equal to a margin of $\frac{1}{8}$-in. all round for planing down to exact size, and is therefore only required on planed plates. It is the custom to order flats, angles, channels, and all sectional material to the nett required dimensions. It is often possible to save a little weight in ordering short lengths of angles and flats, etc., by putting several together to form long bars. Thus if, say, 1200 flats 3 in. × $\frac{1}{2}$-in. × 1 ft. long were required, or 1200 angles 3 in. × 3 in. × $\frac{3}{8}$-in. × 1 ft., they could be cut from 50 bars 24 ft. long, or, adding to this $\frac{1}{4}$-in. for each cut required, 24 ft. 6 in. long. Material is saved, because if the mills cut them to length they would all come in a trifle long, and this would have to be cut off each one. Since cuts must be made at the yard, they might as well be done first as last. Besides, the mills charge generally about five shillings per ton extra for cutting to short lengths, and, again, the girder yard does not care for a whole heap of these lying about for some time before they are required; they are only liable to get lost or taken for something else; so that there are many advantages to be gained.

A copy of the tests and conditions of rolling and inspecting from the engineer's specification should be put on each order sent out as a precaution against trouble. The mills should have no need to have to refer to separate letters or statements *re* same; if they are put on the order, trouble to both parties is saved. Needless to say the order lists should be very carefully checked with the working lists; this is responsible work and should not be left entirely to juniors. The working lists should be read out, and as the various quantities arrive they should be ticked off or the numbers set down in pencil opposite the proper items. Since any item in the order may be compounded of a number of small ones from the lists, aggregates must be particularly ascertained. It must also not be forgotten that when short pieces are ordered in long lengths, the working lists are to have a note to this effect put upon them.

The order safely despatched, attention can be given to the getting ready of the drawings for the shops, though of course this could have been got on with so soon as the working lists were made. The general state of unfinish and vagueness which pervade many of the drawings received often render it necessary to draft them completely afresh. At times this is so bad that the list of materials cannot well be got out until some drawing has been done, and where this is the case much delay is bound to occur. Occasionally, and generally with Government or railway work, nothing wants doing save the making of exact copies for the shops, and the drawings can be turned directly over to the tracers, thus saving much expense and time to the manufacturer. More often, though, there are various details which are not clear, or essential views omitted, and which must be rectified. If the job is urgent and part of it is quite clear, so much can be at once sent into the works and a start made with the templates whilst the remainder is being elucidated.

It will be the chief draughtsman to whom the efficiency or otherwise of the shop drawings is due. More rests on his shoulders than many managers are willing to admit, for on his arrangements and system will depend the whole sweet working of the job. If his drawings are clear and precise on all points, his lists absolutely correct, and he sends them out judiciously and at proper times, there cannot well be room for hitches in making, other than trouble with the men or machines. If, however, the drawings are incomplete and the lists inaccurate, and both are sent out irregularly without any regard to girder-yard conditions and wishes, his office will be a constant rallying point for foremen, template-makers, and platers seeking explanations of obscure points or the reconciliation of conflicting statements. Work cannot be made either well or quickly under such conditions, to say nothing of the added cost. The "chief" should always personally inspect everything before it goes into the shops. In a small or medium-sized office he will have time to generally superintend everything and be able to satisfy himself at every stage that matters are properly developing. In a large office, where there may be fifty or sixty draughtsmen, his many duties will not allow of much attention to details, which he must delegate to the various leading draughtsmen; but he should always make time to assure himself that his system is working correctly, and that drawings and lists do not go into the shops except in proper form. There is bound to be a vast difference between the conduct of a large and small drawing office, and what is suitable for one will not be suitable for the other. In the one personal oversight at every point being practicable, the question of routine working is not perhaps so vital; but in a large establishment it will be absolutely necessary to successful working. With a well-thought-out system in proper operation, work will come through smoothly and quickly and with the minimum of errors. The personality of the chief and his own habits will infallibly shape the general conduct of his assistants; a slack chief will have slack men and *vice versâ*. Mistakes will happen at times in spite of every precaution, but some men are noticeably

freer from them than are others; and some offices will, in the same way, have less to worry them on this score than will others. With proper routine a mistake will not be due to carelessness or incapacity, but only through the human failing of not being always able to guide destiny.

In very few constructional offices is it now the practice to ink in drawings, or indeed spend any more time on them than just sufficient to thresh out what is wanted in pencil. If full drawings have to be prepared, they will be the barest outlines only; all the fill-in work will be done on the tracing, which will then become the drawing for the job. This is much quicker, more economical and satisfactory than the older way of inking in and filing away cumbrous sheets of thick drawings. The tracing, which should be on the best linen, takes up less room than does drawing paper, will stand very much more handling, is generally clearer and easier to read, does not get dirty, and will not tear easily. The best linen is recommended, because in the end it is the cheaper. Through its greater transparency a pencil drawing will be the more rapidly traced, whilst the photo copies will be all the clearer and sharper. Common linen is very suitable for shop use when blue prints are not suitable, and for erection tracings, but it should not be used for office copies.

The question of what is and what is not necessary to be shown on shop drawings is a debatable point. Some American works separately detail every small part of a girder or structure, so that the template-maker has no thinking to do, but only makes his templates, exactly as the small-scale reproductions given him represent; in others, no templates as we know them are made. British practice is to show and dimension everything, and to let the template shop do a little scheming. Both systems seem to work well in their respective homes; probably they are each best suited to their own class of work. Anyway there seems no reason why our present practice should be altered; the only thing is to ensure that it is always working at the highest state of efficiency. This will be so when the minimum of draughtsman's time gives the maximum of information to the shops, or when the template-maker gets all the details he needs at the least trouble to the draughtsman. General elevations and plans should always be first given, even if to a very small scale, and then all joints and connections should be drawn to a large scale. The aim should be to so arrange that everything can be thoroughly followed and quickly read. Dimensions should not be spared, but be profuse; it ought never to be necessary to use the scale on a drawing in order to determine a size. If a large Linville girder, say, is being drawn, an elevation to ¼-in. scale is desirable, or, if several bays are exactly alike, to ½-in., when it can be broken, with a plan to the same scale under. On the elevation the junctions of diagonals and verticals to booms should be lettered, any two or more alike having the same letter, and larger details of each different one should be given, say to 1½-in. scale. The booms should be separately drawn in diagram to exaggerated scale, so that there may be no error regarding them, and the joints of webs and main angles should be clearly shown. The riveting in every part

must be precisely stated or shown, and given in detail for all joints; in fact there must be no room for doubt left in the mind of the workman as to the intention at any one point, otherwise the drawing fails in an essential. Better give too much information than too little, though neither course is true draughtsmanship. Curiously, it is often in the simpler work where there is dearth of information; in drawing a web-plate girder, for example, of either single-web or box formation, and especially if there be many connections thereto, the draughtsman is apt to be content with an elevation and section at centre. It may be all logically arranged in *his* brain, he may be able to mentally see every single rivet, but unless he can lend the brain to the template-maker, it is not going to be clear to him unless everything is shown in black and white. A web-plate girder needs an elevation to as large a scale as can be conveniently drawn with the riveting plainly marked, a plan half on top and half through the web, and sections wherever there is a connection, one section to each different connection and a section at centre. If there are many flange plates, these should also be drawn to an exaggerated scale for both flanges, so that the joints can be plainly indicated. Figure everything; the lengths of the plates, the position of all joints, depths, thicknesses, rivets, and sizes all through. Leave nothing for the girder yard to decide, or to chance. The draughtsman is the designer, not the plater; and if he is of any use at his job, he will know intimately every little corner of his design. In more complicated structures, more drawing is necessary for office information as well as that of the yard. In an involved roof, such as is becoming the fashion in large public halls or buildings, theatres, and the like, the draughtsman has to make many views before he can grasp entire arrangements, and the works benefit to this extent; the most likely things to be forgotten are specific details of slight variations in connections; yet connections have to be made, and so someone has to worry them out. It is a vast deal cheaper to do all such worrying in the office. The draughtsman should always try to put himself mentally in the place of a stranger to the job, and remember that the stranger's sole source of information lies in the drawings which are put before him; he would be better able to realise then how vexing and disconcerting it is to search view after view in quest of a dimension or a guide to a small connection. Template-makers' and platers' time is valuable time, and when spent in searching drawings is so much money lost.

When the drawings have been finished in pencil, they are to be traced. Some works still believe in sending nothing but cloth tracings into the yard, but the great majority have adopted one of the many photographic processes and use prints. Cloth tracings are certainly preferred by the works, and where a great deal of handling has to be done are still unbeaten; but for average work, which is quickly in and quickly out, they are too expensive. In the first case, the cloth costs anything from two to five times as much as does sensitised paper; and in the second, it means, perhaps, two or three days of a draughtsman's time against a few minutes by the photographer. A girder drawing which will take a whole day to trace, and will cost, say, seven

shillings in the tracer's time and one shilling and sixpence for material, will cost threepence in time and sixpence or ninepence in material at the outside if photographed. Of course, the office copies must always be traced, and these are usually utilised as the negatives for the yard copies. Tracing paper is not satisfactory, except for use in sending away. It is altogether too fragile for either office or works use.

There are many excellent photographic processes now which can be employed. The old and well-known white lines on blue ground or ferro-prussiate paper, blue lines on white ground, black lines on white ground, and brown lines on white ground may be instanced. Of these, those needing the water-bath only are preferable—chemicals are not only messy and expensive, but are so apt to rot the paper through improper use. The ferro-prussiate paper is the cheapest and best for all-round work still; but it cannot be coloured or worked on to any extent after making. The water-bath, black lines on white ground process, which can be obtained from most makers now under various names, is the best when either of these points is a consideration. It is slightly more expensive, but its advantages quite outweigh this. With the brown process, prints can be procured from the drawing without the medium of tracings if the lines are in good black ink. This is done by first taking a negative from the drawing and then a print from the negative. The texture of the drawing paper is apt to show a little; but in those cases where important plans can only be loaned for a few hours, its use is of great value, and such small drawbacks need not be counted. It will pay, though, when a print is obtained, to take a tracing from it, as the paper sometimes goes wrong subsequently.

It is possible to obtain both sensitised paper and cloth, and the latter is of value for rough handling. It is not quite so easy to manipulate perhaps, but at times this would not weigh with its advantages. An electric printing outfit is almost indispensable to the modern drawing office to supplement the daylight frames; by its use printing can be carried out independently of the weather. In fact, in large offices the work could not be got through without its aid.

The question of how many copies must be made for the works will depend on the size of the establishment. For a small place one copy of each drawing will suffice; for a large one two sets should be made—one for the foreman's office, the other for the shop. It is the rule in some works to make separate sets for the manager, foreman, template shop, and plating shop, and extra copies as required. Naturally this runs to very great expense in the course of the twelve months, though not perhaps seeming so heavy at the time. More than three sets should not be required by the largest yard, one to be kept in the works or foreman's office, and the other two for the template shop and erecting shop respectively. What has to be guarded against is that more time shall not be spent in going after drawings than another set would cost to make, and this must depend largely on the individual peculiarities of each place. The cheapest course is the one to be pursued by every establishment.

Many offices are slack in their attention to erection marks. Whether the works has to erect or deliver only, someone has got to put the work together again at site—our railways will not yet take bridges and pit-head stocks in one piece. Generally it is left for the shop foreman to paint certain hieroglyphics on different joints, and a junior from the drawing office copies them and puts them on a tracing or print to serve for the erectors. This is not business; it is a most haphazard way of treating matters. Erection marks should be arranged in the drawing office. The objection that the draughtsman seldom knows how best to joint work for despatch is unsound. If he does not, then he is lacking in his business knowledge, and it is time he remedied matters.

A good system of checking drawings and lists into the shops should always be in use, otherwise continual trouble will be the result. Every separate tracing, drawing, or print which leaves the office should have an identifying number. This should be entered into a book properly ruled with columns for the number, date of leaving office, job, works mark or contract number, destination, whom sent out by, and manner of sending, somewhat as follows:—

Drawing No.	Date.	Job.	Mark.	Destination.	Sent by	How sent.
01284	14/3/04	Bass' Brewery contract No. 3.	B3.	Girder shop	A.B.	Boy
01285	,,	Troon road-bridge	T.R.	Surveyor	A.B.	Post
01286	,,	Johannesburg tanks	J.T.	Glynn & Co.	A.B.	Post
01287	Etc.	Etc.	Etc.	Etc.	Etc.	Etc.

A complete register is thus kept which can be referred to at any time, and which puts all essential facts beyond cavil. The "mark" or contract number, whichever is variously preferred, is merely the shop name for a job. It is usually considered best to distinguish work by such means, and its real destination is not then supposed to be known in the shops. It is very questionable whether there is any advantage, but the practice is general, the only point being whether letters or numbers are the best to use. Personally, letters are preferred, since they can be arranged to form some clue to aid the memory of the staff, whereas it means a distinct effort to carry in mind isolated numbers. In some works a further column is added for the foreman's signature when receiving drawings, but this is of doubtful value. If the office is large and there are many draughtsmen, it will be better to add columns for "drawn by," "traced by," and "checked by"; otherwise, in case of errors, it would be difficult to locate the responsible parties. On the whole such a register should be kept as simple as the size of the office will allow.

With regard to the sending out of the working lists, these ought to be press-copied, so that an exact duplicate will always be in the office. It is a

great improvement to type instead of write them, and then they can be manifolded. A small office could not keep a really expert typist going, and occasional typing by juniors is not to be recommended when so many figures are involved. But in a large place two or three typists can find work, and typed lists are preferable in every way to written ones.

When payment is to be made by weight, either calculated or actual weighed weights, the working lists will be used on which to base the calculations. Since they contain every piece of metal used, large or small, they are obviously the very best thing to utilise. Each item can be readily and very quickly run out in pounds and totalled and turned into tons and cwts. for each complete girder or piece. A little practice will enable one to carry the weights per foot-run of sectional material in the memory, and it is then only a question of a few minutes to determine what is required. Needless to say an independent check should always be given to such figures. It is customary to estimate the weight of mild steel as being 40·8 lbs. per square foot of 1 in. thick, and all tables are drafted on this basis. Calculated weights should be compared with the results shown by the weighing machine, when errors on either side can be detected and adjusted. It is astonishing how closely the two will approximate; if lists are thorough and material exact to size, a variation of 2½ per cent. either way or an extreme of, say, 5 per cent. is generally all that is found. Should this be exceeded, the matter should be further probed.

It must not be forgotten that copies of those items of the specification which refer to the method of doing work must accompany the drawings into the shops. These should be properly booked out, so that there may be no mistake as to their having been duly sent.

Questions of office equipment, arrangement, and usage are not properly germane to the present purpose, nor the relation of the drawing office to other departments, or the business and financial end of the works. They are far too big and important to be treated in any but an exhaustive fashion, and this is not now permissible.

CHAPTER XIII.

THE TEMPLATE SHOP.

THE girder-shop foreman, who will probably be more or less familiar with the drawings through being consulted on points thereon before he really gets them in the shops, should, on receiving them, at once master them thoroughly. If there should be anything wrong in them which has been overlooked by the draughting staff, it will save much time if found before work is actually commenced. Many times awkward points are not seen until the full-size setting-out is done, and these, of course, he cannot discover; but so far as workable joints, riveting, and all minor details are concerned, he should assure himself that all is in order. When a foreman gives out drawings to his men without having thoroughly examined them himself, he must spend time looking into them as questions arise, wasting not only his own time but his men's. There is always bound to be a certain number of points on which a man must consult his foreman; in fact, few workmen would feel happy if they could not raise some query or other on every job passing through their hands. If the foreman knows his work he will have an answer ready; if he has to pore over the drawing and unravel things there and then, he is but proving that he is not doing what he is paid for—saving his employer's money.

The next step is to get the templates [1] made, and the material sorted out and put ready as it arrives from the mills.

A recognised essential nowadays to a structural works is a good template floor. Years ago the common way of making templates was to set work out on platers' tables. In the beginning of the trade the actual plates and other materials to be used were laid down either on a floor or trestles, and marked off for shaping and punching by hand. This developed into putting down low cast-iron trestles and laying on these boiler or other plates, on which setting-out could be done; then templates were made of thin sheet-iron to this setting-out and used for marking off. Occasionally plates for other jobs were utilised—time was then no factor—until they were wanted; usually the trestles would be placed parallel with others to form long rows, perhaps 40 to 100 feet in length, and if the job was irregular in shape the trestles

[1] Templates are dummy reproductions in wood or iron used to mark off the actual materials and ensure accuracy in the several pieces of a girder or other structure.

and plates would be pulled about to suit. That was in the days when a 100-foot girder was a big thing and setting out did not involve the awkward angles and long striking points it does now. As jobs grew in size and templates got bigger and bigger, the sheet-iron method as steadily went out of favour. Accuracy became more and more important, and half a dozen thin whipping sheets of iron would not butt together with the necessary mathematical precision; they were awkward and inconvenient to handle, besides being expensive. So the practice grew of utilising wood in its place, until to-day fully 90 per cent. of the work made is put together through the agency of wooden templates. The old platers' tables had also to be discarded; they were no longer wanted to lay material upon to see that it coincided with the setting-out, and they were too cumbersome and not anything like large enough for the growing work. They served very well so long as plate or open-web girders up to 40 or 50 feet span were the general run, but they were not economical over these limits. True, some very fine work has been done upon them. The methods used for a Crumlin viaduct are not to be despised, but that they were not the best way of doing work is proved by their gradual abandonment and the general adoption of the spacious template-shop setting-out floor.

With the use of wood has grown up a body of skilled template-makers—many of them old pattern-makers or joiners—and the time necessary for turning out templates has through their agency been cut again and again. A good template-maker will only need to set out on the floor when angles or lengths cannot be otherwise accurately determined, or the precise sweep and contour of a curve with many radii has to be obtained. He has a grasp of what he is doing, and can work directly from the drawing on to the wood for all ordinary cases. In some American works he seldom even visits the floor; draughtsmen come down and set out full size everything required, so that they can make the shop drawings absolutely complete in themselves. There are advantages in this, but the disadvantages are that the template-maker is deprived to a very great extent of the opportunity in awkward cases of fitting his work on the floor to a setting-out and thus proving it. If anyone's time has to be spent on the floor it is better to let it be the template-maker's. He is at a less wage, and has not to study his clothes when stooping and bending or kneeling; he will do it both quicker and at less cost.

The floor is usually a boarded one, and will vary in size according to the kind of work carried out. From 2000 feet square upwards will be normal sizes, though in small works there are many considerably less than this. The joints should be good and close, and for first-class work the floor should be planed and trued after laying. The setting-out will be done with steel tapes, chalk and line, large set and other squares, ordinary trammels and compasses, and straight-edges of various lengths. Running round the floor, or at one end or in a separate annex, will be the benches. It is better for them to be placed away, so that there will not be any traffic over the setting-out floor, which should be taken care of. There will always want to be at least one side of

the floor benched, so that when particular work is being fitted on the floor alterations and settings may be done expeditiously. But all the ordinary benches are better away from it. A good plan for such a shop is shown in fig. 33.

Light is, of course, a *sine qua non*, so that, besides the side windows, there will be continuous roof glazing, which must be thoroughly whitened in summer-time. The large doors at the end of the floor should only be opened for the passage of long templates made on the floor; for all other purposes the other two doors must serve. Such a shop need not be high—it is floor-space which is wanted, not height. On mixed work a building of this size would well serve a medium-sized works turning out, say, 5000 tons per annum. If the work was entirely of a light and intricate character, a bigger floor-space would be advisable.

The timber generally used is a good quality pine or red deal, and is bought sawn in widths of from 3 to 5 or 6 in. and about $\frac{1}{2}$-in. thick for the framed

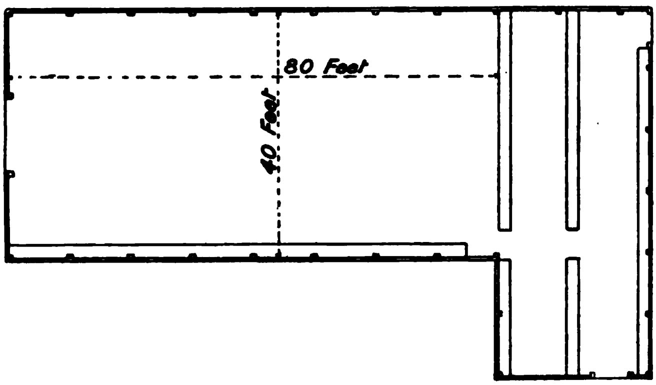


FIG. 33.—Plan of shop.

templates, together with 11-in. wide boards up to 1 in. thick for the solid templates. At some works a cheaper timber, such as white deal, is used for the bracings to templates, the better qualities being reserved for cases in which work has to be put upon them. A good timber gives a good template—other things being equal—and is worth the difference in cost in time saved.

The template-maker does not need a large kit of tools—a panel and tenon saw, brace and bits, smooth and jack planes, one or two chisels and gouges, squares and bevels, a few gauges, hammers, rules, and straight-edges, etc., suffice for his wants. A steel straight-edge fastened to the raised back portion of his bench, 25 feet and over long and accurately divided into $\frac{1}{8}$-in., will be of considerable assistance. A mitring and squaring machine in the shop is useful, but power tools are not necessary; there is no work for band and circular saws, mortising and tenoning machines, etc. On some jobs the employment of light portable pneumatic boring tools is an advantage, but to be

any saving over the ordinary brace and bit there must be a big straight run of holes to be bored. For a few holes they are useless, since the time spent in picking them up and arranging the pipes could be spent in doing the work with the brace. They are therefore of most use in shops dealing with heavy structural plate girders and the like. Fig. 34 shows one type of these little machines. They weigh about 14 lbs. each, and are not therefore too heavy for prolonged use. In a large shop there would be several stationary air-supplies at convenient points, and each machine has about 20 feet of flexible tubing attached, which can be connected at will to the nearest supply. The equipment, therefore, of a template shop is not a very serious matter.

FIG. 34.—Pneumatic borer.

On receiving the drawings the foreman will apportion them amongst his men, whose duty it will be to make skeleton facsimiles of all plates or sections with holes in them, and of all cutting, splaying, mitring, or jointing at an angle; and generally of all pieces to be used which have work put upon them other than plain straightforward planing, etc.

The operation of template-making is not difficult work, but it calls for great exactitude and facility in reading drawings and setting out. A good class of men is required, especially in shops dealing with the more complicated structures. The *construction* of the templates is of minor importance compared with the ability to set them out quickly; hence handicraft is not of the same moment as it is, for instance, in pattern-making; at the same time, a smart man all round will have an advantage in that, after setting out, he can clear away quickly ready for a fresh job.

Small templates, such as corner and connecting plates, small brackets, etc., are simply solid pieces of wood of thickness commensurate to their size, cut to the right shape, and with the same sized holes in them, in the exact positions required, as must be in the steel plates. These are laid on the

roughly sheared plates, which are then marked off to suit. The following figures will be typical of such templates :—

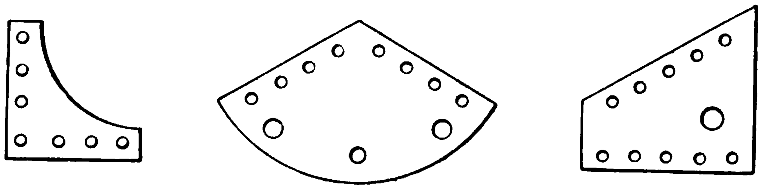


FIG. 35.—Templates.

It is evident that by their employment any quantities of plates may be made in exact duplicate of each other. There is a "face" side to each template, and this will be laid next the piece which is being marked off.

Large templates are made in skeleton. That is, narrow timber is used, and this is framed together rigidly in such a manner that it gives all the information wanted at the minimum of timber used. Thus a flange-plate template would look like fig. 36. Every hole required, it will be seen, is put in its proper place, so that the only thing to do in the yard is to lay the

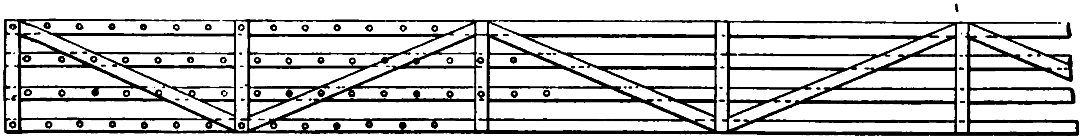


FIG. 36.—Flange-plate template.

template flat on the material, clamp it in the best position, and mark through. The "face" side will always be flat to allow of proper bedding. The diagonals shown are merely stiffening pieces to prevent racking or getting out of shape, and are put on in various fashions to suit the man's fancy. Of course, if holes were required in the parts they cover, they would be put in.

Angles are marked out by means of two strips fastened together at right angles and holed as necessary; the flanges and webs of joists by strips or framed pieces according to size, as above; generally for stiffeners strips are sufficient, as most works possess proper blocks for bending; the aim being in all cases to make the templates so that they can be used in the handiest manner consistent with accuracy. It is the template-maker's duty to verify the holes and joints everywhere; the shop takes no cognisance of these until it comes to put the work together, so that all responsibility rests on him. All minor parts must be marked off from the principal ones. One setting-out must do as much duty as possible; thus main-angle templates must be marked off from web do., flanges from angles, or corresponding orders; by these means exact similarity is attained, and if the material is properly marked off and manipulated it is evident that everything will be in agreement. In

fact, it is well known that so much faith have Americans in this system of work that it is seldom that jobs are put together in the shops to any extent; generally all assembling is done for the first time at the place of erection. English engineers do not care for this, but it is really much the most sensible plan so far as ordinary straightforward work is concerned. For intricate work the expense of putting together in the yard is well worth incurring, and of course, all members which can be riveted whole in the shops will alway be done so, since shop work is infinitely cheaper and better than "field" work; but there is much steelwork made on which we could well take a lesson from our rivals.

In open-webbed girders of the lattice type many bars are alike, and, if the design is favourable, possibly only four or six strip templates may be necessary. In girders of the Linville type each tie and strut may be different, so that separate templates will be required for each. They will have to be properly marked, so as to indicate which is which, and the plater will be responsible for their due selection. When tie-bars are large and have only to be cut and holed at their ends for connections, full-size template ends would

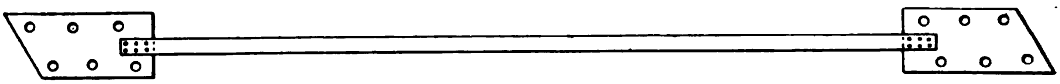


FIG. 37.—Strip for connecting templates.

be made, and be connected together by a smaller strip to the correct length required, as shown in fig. 37. In setting out such ends, the whole joint would have to be put down on the floor, so as to obtain correct angles of bars, and then the templates would be carefully made to the setting-out.

The timber used is not planed or dressed, except where necessary, as this would only be waste of time. Nails are better than screws for fastening parts together, as they are more quickly driven, the parts can be steadied together better, and they can be clenched on the underside if wished. The templates are sent out of the shop just as they leave the bench, and are not painted or protected in any manner. Usually they are only wanted in use for a very short time, when they may never be required again. Some of the more valuable ones, or those for stock work, such as the Crown agents give out, are worth taking care of, but the remainder are re-used where possible or destroyed; housing room is dear unless there is commensurate benefit.

It will be easier now to understand why it is so much cheaper to be at a little trouble in designing so as to get as much similarity and uniformity as possible everywhere. Take the case of a long girder. It is obviously impossible to get templates made 100 feet and upwards in length, just as it is not possible to get flange plates of that length. Now a 100-foot flange will be composed of several plies of plates with many plates to each ply. If the plates can be largely of the same lengths, and the rivet pitches be regular for several plates, it follows that one template can do duty where

otherwise several would be required, and it is possible for the flange templates to leave the template shop with an inscription on to the effect that so many are required off, instead of one only. This not only makes a substantial difference to the cost of templating, but also to the cost of marking-off and all subsequent operations.

The great essential in templating is obviously accuracy. Without this it has no virtue and good work cannot be done. "Near enough" is no phrase for this shop—everything must be exactly right. A slack man at his trade is no use here, and every precaution must be taken with both men and tackle to see that a high standard is maintained. The foreman should always give attention to all work turned out; so long as the "fountain head" is right other mistakes will be hard to make.

It is the custom to mark countersunk holes by putting a circle of paint round them, the marker-off denoting this on the steel in the same way, when it is properly attended to by the puncher and driller. Perhaps in some girders one long template may be made for a long plate or two, and then cut down by degrees to suit the smaller ones; this is always possible where the riveting is well arranged; odd holes which do not happen to come in may be plugged up and fresh ones put in in the new place required. In some yards templates are not made for every little plate; for instance, the bearing plates on a girder will be marked through from the flange plate to which they are to be attached; the end plates of a plate girder will be marked off from the end angles, and so on. It is sometimes economy to do this—a good deal depends on the plater in charge. A good man will save a deal of templating very often, because the foreman knows he may be trusted to do things properly.

When templating was done in the old way the plater was a very important figure in the girder yard; he had to do the whole of the setting out and making of templates as well as superintend the assembling. Naturally he commanded high wages and was thought much of. In some works in the North of England to-day he can still make £4 to £5 per week, and sometimes more. He is, however, a declining force, and there are several shops employed on repetition work where the "plater" is but a glorified labourer with the handsome wage of twenty-six shillings per week. When the template-making was taken out of his hands he lost caste rapidly, and the average works—given the right foreman—can get competent men to undertake what is left of his duties for from thirty-five to forty shillings per week, with perhaps another ten shillings for a specially good man. Template-makers' wages vary very much in different districts; they are much higher in the North of England than in the Midlands or the South. The standard wages for pattern-makers being perhaps on the average thirty-six shillings per week, the average template-maker does not usually expect much more; perhaps thirty-eight to forty-two shillings per week would cover the usual rates, with up to another ten for a first-class leading hand.

Reckoning this way, it is evident that the new system is far before the old

in point of cost; the old cannot be compared with the new, so far as accuracy goes either. The system of wooden templates has helped not a little to bring down the price of steelwork, so that it is now one of the cheapest constructional agents known. The old way of making them of sheet-iron was slow and tedious—metal cannot be carved with hand-tools in the same way that wood can, and when made they were awkward and inconvenient to handle. Of course, if they were worth keeping they were practically indestructible, but the small percentage of which this could be said did not help much.

Some works make most of their small templates—the connecting and angle plates, etc.—out of thin tin or zinc, and the method is to be commended when there are many to be taken off each. The zinc particularly is easy to treat with hand-tools, and labour thereon is not very costly, whilst the template will be lighter and more easily handled than a thick wooden one. Most substances have at one time or another been called upon for this work, and there is no reason why anything handy should not be used. Stout millboard makes excellent small templates, whilst even brown paper is not to be despised.

As regards methods of making, much might be said were it not that such a lot depends on the drawings. In this way: given a straight run of 4-in. riveting, a wooden strip can be laid against the steel bench straight-edge rule and the centres marked off rapidly by means of a square and pencil or scriber. If, now, it is the stiffeners which are in even dimensions, and the riveting has been left to take care of itself, progress will be very slow, and in some cases the dividers will have to be used to laboriously step the centres out truly. Since it is the *setting-out* which is the principal part of the work, it follows that on the drawings will depend the methods to be used more than anything. Of course a handy man will have many tricks of doing things which give him an advantage, but there is no patent way to quick work yet discovered. A good knowledge of geometry is bound to be a great help in difficult situations, but such information must be sought in the proper quarter. Successful template shops are those possessing the most brains, not machinery, and a talent for organisation of work. Many helps to progress may be made, such as specially divided staffs for different regular rivet pitches, fixed trammel heads with steel rule let in floor for taking off radii quickly, fixed gauges for rivet centres in different regular-sized angles, tables for the same for irregular angles and such-like small adjuncts, the value of which depends more on the will of the men using them than on anything else.

It will be found of great help to store the timber to be used in a proper place. If the strips or boards become scallowed, they cannot make first-class templates. Attention should also be paid when buying to see that they are free from knots, shakes, and other imperfections, and that they are perfectly dry and well-seasoned. Green timber is an abomination to a template-maker. If timber is bought which has an awkward grain, or is dead or sappy or

wet, the brace cannot be expected to put perfectly smooth holes through it, yet these are necessary to good work. Parsimony in this direction is not economy.

It should always be remembered that the mission of templates is to minimise skilled shop or yard labour. They are an instance of specialisation, in that men devote themselves entirely to their production instead of making and then using them. The men who use them do not need to be so highly skilled, consequently a saving must be effected if the skilled man can always be kept on the skilled work. To be a success, however, such a system of labour must provide that the unskilled man is not presented with difficulties beyond his powers; that is to say, the templates made must be the essence of simplicity; there must be nothing roundabout or demanding the exercise of brain-power in their use. One thing at a time on any one template and then a journey to the shop for alterations, however small, is a golden rule.

CHAPTER XIV.

THE GIRDER SHOP—I.

A GREAT change has come about in the places of manufacture during recent years. Up to a decade ago it was usual to do all assembling in the open air; now it is usual to do it under cover. Certainly there are still many works dependent on the girder "yard"—some of them amongst the largest and most important in this country; but taking the known works of the world it is pretty safe to say that the majority now work under cover, or are making arrangements for so doing. The principal reasons for the change are to be found in the influence variations of weather are bound to exercise on outside work; men will not work in pouring rain—they cannot work in snow. Another reason is the short daylight hours in winter and the impossibility of arranging satisfactory illumination—especially as this is most wanted just at the period when the elements are inclined to be the most unkind. No one who has not tried it can know the wretchedness of trying to work on a push job on a winter's evening with rain falling and half a gale blowing. What light can be obtained is dull and fitful; it is most difficult to see what one is doing, and to add to this vexation the rain is soaking in to the skin and the wind is beating and piercing one with cold. It is hard to ask men to work under such circumstances; it is most difficult to keep them at it. Riveting becomes an almost impossible task; the rivets will not heat, or, if heated, cannot be kept hot; the holes can only imperfectly be made out; everything is clammy and wet to the touch; and everyone is sensible that the best work is not being done, nor can be done. The difference in output between the winter and summer months is alarming, and it quickly caused masters to consider whether summer conditions could not be made to obtain during the winter.

So girder yards began to be roofed in, and then came the girder "shop"; and during the months when its covering is a protection there is no doubt but that it radically affects output and makes possible that which previously was impossible. A good many engineers regret the change, and all are by no means unanimous as to its wisdom. Given good weather there is no gainsaying the fact that work is pleasanter and can be got through quicker in the open. Men naturally work better outdoors than in shops—provided there is

not too high a temperature; there is a greater sense of freedom and space, and an entire absence of the objectionable resounding of every hammer-stroke and little noise. Then again, no matter how big the shop scheme, there is not the space available—or does not seem so—as there is in the yard. Girder yards never seem so choked with work as do shops; or rather it never seems possible to put quite so much work on the same ground in the latter as in the former. The one is full and choked up when the other could still find a little more room. Another matter is that shops are not elastic, and are bounded in height as well as length and breadth, and so many jobs have to be differently managed when done under cover; at times they cannot even be properly put together, and this may be a serious drawback.

From the designer's point of view the best thing about the shops is the protection they afford to the work in hand. With the chances of oxidisation so much diminished, a better job must ensue, and there is no question but that the change is all for the better from this standpoint.

The point which specially appeals to the maker is, is there money in it? Do the shops pay for the outlay involved? It is an easy task to buy a field or two, put up a little shedding to cover the main tools, and have all the work assembled in the open; the capital involved is not very great. But it alters considerably when the whole area has to be covered in and immense shops put up of a height commensurate to the work to be undertaken. What was a flea-bite becomes a most serious undertaking, and the capital necessary a very large amount.

The best answer will be found in the fact that it is experience which has dictated the course, and this is, after all, the very best guide we can have. Hitherto the greatest difficulty has been to make the large tools necessary for work of any size pay properly by keeping them at their maximum output. For perhaps seven months of the year they worked well and fairly constantly; for the remainder they would be on half-time or less. This meant that plant which could deal with 100 tons per week during good weather hardly touched 50 tons during bad and unfavourable weather, and an output which ought to have been 5000 tons per year was actually only about 4000 tons. At this latter figure perhaps only a moderate profit was made, and if looked at only so far reason would seem to be against the wisdom of embarking further capital in shops. But if, given shops, the output can be largely increased for the same tools, and the vast sums formerly spent on totally inefficient lighting be saved, a different complexion is put on the matter. It was always a problem how best to light a yard. Electricity is now available and in a measure mitigates it; but previously the crude oil burner was about the best which could be got, and this was terribly expensive. It was picturesque—perhaps; but effects of this nature are not exactly the aim of girder yards. During some push work one winter at a works where the writer was engaged, forty barrels of this oil were consumed every week! Compare this with the cost of lighting shops, to say nothing of the gain in illumination!

The secret of success is continuous maximum output at the lowest unit

expense. Only in this way can the big tools of a modern girder yard earn a profit to their owners. The ideal method of working is the continuous plan, when work is never ceased night or day. For many reasons we have to fall short of the ideal—it is not practicable in all places, nor, if practicable, is it invariably profitable, such is the contradictoriness of human nature—so the next best plan must be taken, and efforts made to ensure the utmost results during the accustomed hours of labour. It seems peculiar that so few works are successful with the twenty-four hours' system. It has been again and again demonstrated that it can be successfully worked, and again and again denied after every effort seems to have been made. All business men hanker after its glowing promises; few are fortunate enough to be able to inaugurate and maintain it. There is, of course, much that can be said against it, and the probabilities are in some places it is quite impossible, whilst in others it might very well be run, even for the same trade.

Be that as it may, every place is vitally interested in obtaining the utmost results during the hours it is supposed to be actively engaged. If times are from six until five or any other hours, that period should be stuck full of work—everything must be going its hardest and there must be no slackness anywhere. A £500 tool must be demonstrating its worth by its unceasing production—all delays, all waitings are only so much handicap on its showing. But all this can only be the result of the succeeding operations being just as quickly performed. If there is delay in the assembling, the punching press cannot be kept going; if the yard is blocked, the planers, the drillers, the shearers, and the riveters must take a rest. That is where money is lost. So soon as the regularity of the various operations is upset, so soon does loss begin to creep in and profits vanish. That is why big shops are recognised as profitable investments.

It seems almost a pity that the advantages of the yard and the shop cannot be combined. If only it was practicable to make collapsing walls and roofs to be rolled away so soon and just when they could be dispensed with, and be replaced just as easily, conditions of labour would be ideal. As it is, we have to choose the best all-round plan available; there is small doubt this is the roofed-in girder yard. Many works temporise and have both, and it is conceivable that their wants are best supplied in this way. If work is not wanted in a great hurry and jobs of the class undertaken are not often in the market, it might very well pay to do some of it under cover and some of it outside. Whatever the weather, work could then be carried on. But for the busy bustling shops where work is wanted quickly in and out, and a large turnover must be made if profits are to accrue, the covered-in plan is by far the best.

It did not use to be the practice to put all tools under cover even. If a few of the old yards are visited—most of them are by now out of active use—it will be seen that a little shedding over perhaps a planing machine was all the cover they ever boasted. Punching and shearing, straightening and riveting were all done in the open; occasionally a few boards would be

placed like an umbrella over odd machines. It makes one wonder whether the men were cast-iron in those days, or whether the seasons were kinder.

However, whether under cover or in the open, the operations of work will have to be the same, and before we can intelligently discuss the design of proper and convenient shops it is requisite that these be understood.

On arrival at the works, it generally happens that the materials for different jobs are all mixed together, and the first thing to do must be to sort them out according to the invoices. In many works this is not done—for one thing there is often no room available to lay out and properly separate—the steel is unloaded and dumped in a heap just as it arrives, and it is turned over as it is required. This practice is not commendable, since much time is often thrown away in moving different bars or plates many times over. At other places the straightening machines are set to work and draw from the heaps as they come, first straightening and then laying out in proper order. This means that perhaps a few angles for a job may not come through for some time, whilst angles for another job which is not urgent get treated first. Usually like material is sent from the mills in the same trucks; thus all angles will be together, all plates the same, etc. When there is room, therefore, it is not much trouble to at once sort out and lay down in order, so that any one job can be got at immediately, and without the expense of turning over to find it.

When this is over it will be necessary to straighten all bars and plates, and sometimes rolled steel joists and heavy channel sections. At the mills they are carried after rolling to the cooling ground, first being cut whilst hot to the desired lengths by means of the circular saw or other tool. Through being pushed or pulled about, or cold winds whilst cooling, sectional material often assumes a slightly curved form, plates being buckled a little on their surfaces. It is usually possible to get them cold-straightened before leaving the mills, if desired; but since they are bound to get a little knocked about on the journey to the works, and also for cheapness' sake, it is best to do this on arrival. Plates are straightened in suitable rolls made wide enough to take the largest width likely to be used, machines being made variously with three, five, six, seven, eight, or ten rolls, according to the duties they are to perform.

Fig. 38 shows the simplest form in use. Three rolls only are used, of diameters varying from 6 in. to 14 ins. according to the size of machine and the strength required. Strictly speaking, it is a *bending* machine, but in small yards it often combines this with straightening, as it is plain that a tool which will bend will also straighten. In large yards separate machines would be used. It is the most useful type of rolls made for all-round work, being particularly convenient for turning out bent or dished plates having a section like fig. 39, such as are so often used for bridge and warehouse floors. If the end housing is made hinged, plates can be bent to a complete circle, as they can then be readily removed. When intended for such work the width between housings should be as great as possible, so that narrow plates can

be bent longitudinally. Up to 15 ft. is an ordinary width; for medium work 9 ft. will be found convenient. If only intended for straightening and small bending, 6 ft. or 7 ft. might suffice. In different models the top roll is placed either between the two bottom ones or directly over the front bottom one; in the first case adjustment is made by the top roll, and in the second by the back bottom one. There is not much to choose between the two, the first case being, perhaps, the most usual. The bending or

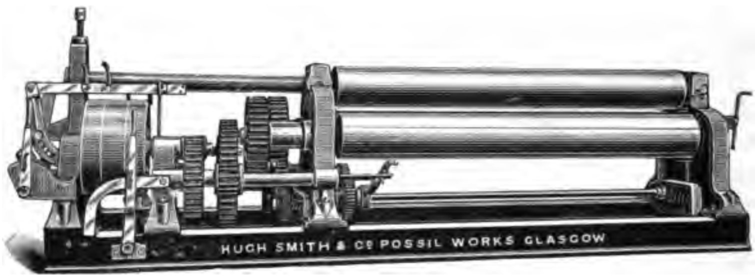


FIG. 38.—Machine with three rolls for straightening and bending plates.

straightening is accomplished, it will be evident, by the approach or withdrawal of the several rollers, sufficiently delicate adjustment being possible by the screw gear provided. It is always better to have a tool heavier than may be thought really necessary, since the service is constant, and at times very heavy work has to be faced. The majority in use are belt-driven, but they are to be obtained adapted to any power.

When multiple rolls are used the machines are intended for straightening only, though by a little scheming they may be used to a limited extent for

FIG. 39.—Section of dished plate.

bending. Fig. 40 will illustrate one with seven rolls, and it will be seen that the arrangement is very similar to the three-roll type. Adjustment may be either by power or hand. For heavy work not more than six rolls are deemed advisable, but eight or ten can be used for lighter material. These machines are not made of such great width between the housings, since there is no use in them being wider than plates are ordinarily rolled, and few shops possess them over 8 ft.; perhaps 4 to 5 ft. is a more general size; wider plates can be dealt with by the three-roll type. They operate by alternately slightly bending and corrugating, and make a very fair job of $\frac{1}{2}$-in. and $\frac{5}{8}$-in. plates; but the thinner plates always require a little after-hammering to make them perfectly true; in fact, even the thicker plates, if required absolutely without wind or kink, must be so treated, though, unless for very particular work, this is not usually done.

The vertical rolls, fig. 41, are specially intended for bending, and are used principally for boiler and pipe making; they have three rolls and are exceedingly heavy and massive, taking easily 1¼-in. plates. They are, perhaps, hardly within the scope of structural steelwork. Fig. 42 shows the new hydraulic plate-benders. Their feature lies in bending plates right to the edge—a result not quite attained by rolls, which leave a small space at the ends unbent. Very quick work is possible by these tools, and they are exceedingly powerful. They possess an advantage over rolls in that

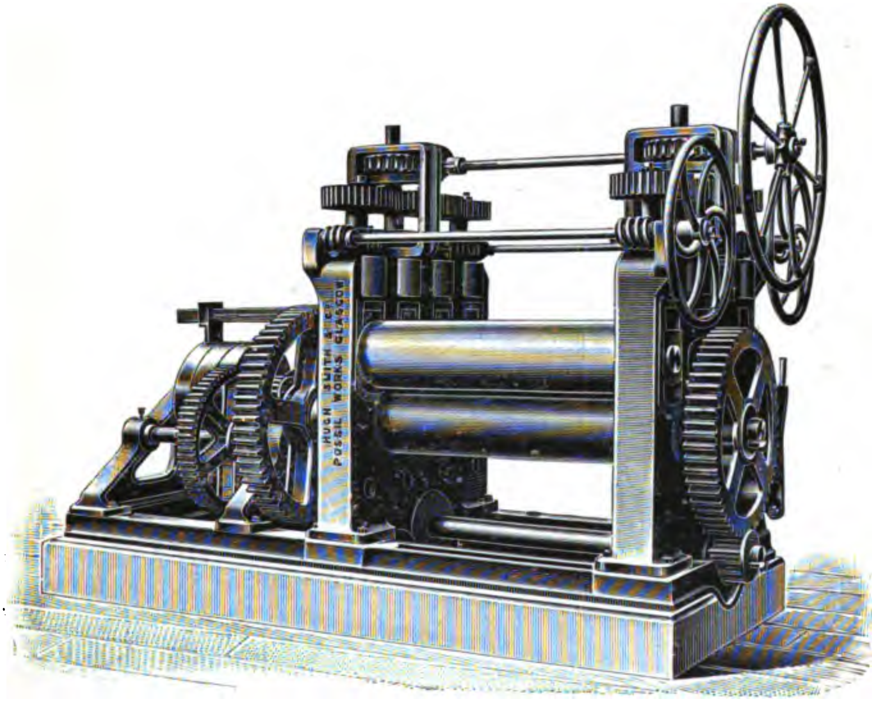


FIG. 40.—Machine with seven rolls for straightening plates.

once set to the correct stroke for any given curve they are independent of skilled labour. Figs. 41 and 42 are given because the tendency of steelwork is to get heavier and heavier, and on certain jobs, notably those in which thick steel cylinders are employed, they will do cheaper work than will rolls. At the same time they would not pay to buy specially for such a purpose unless a much greater run than the ordinary was being dealt with, or there was other work to do for which they are adapted. Tools of this nature are not bought for a few pounds and need constant work to justify purchase. The best all-round plate-bender for the girder shop still remains the original three-roll machine as in fig. 38. In fact, there has been no serious attempt

made to displace it. It covers a very great range, and since a hinged housing has been added (formerly they were both solid), to enable the withdrawal of circled plates, they act very efficiently and, in good hands, fairly rapidly. They are always the first tool to be purchased, and on general work one set will keep a yard going with an output of 2000 to 3000 tons annually, doing both the bending and straightening required. Over this amount a set of

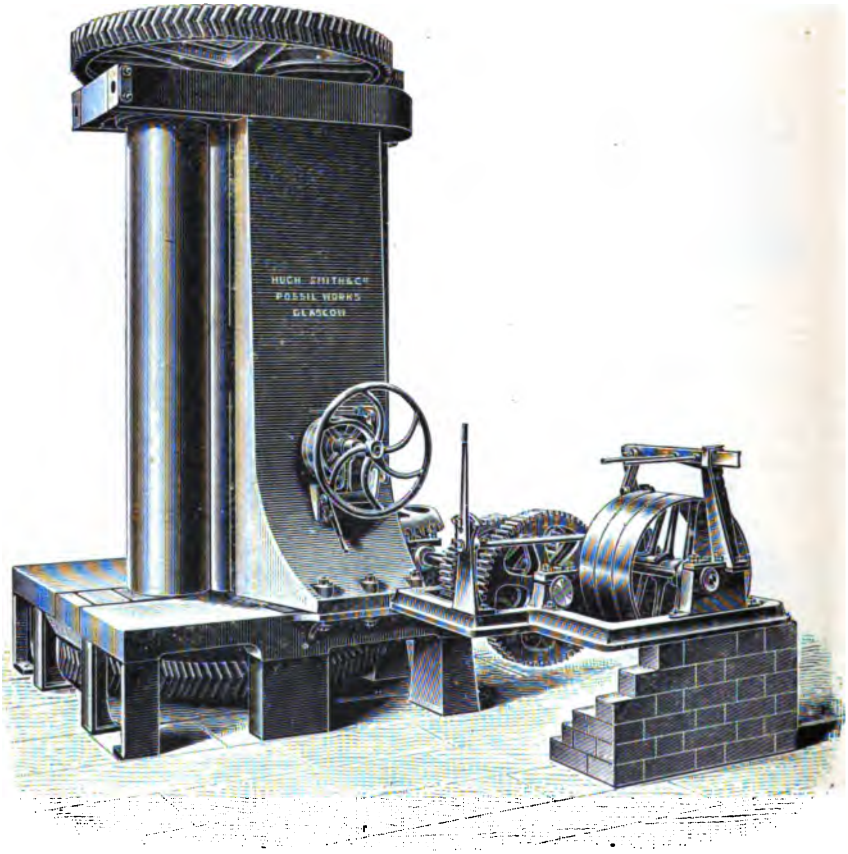


FIG. 41.—Machine with vertical rolls for bending boiler plates.

multiple rolls for straightening only, as fig. 40, might be added, when the two machines would cope with nearly 7000 tons of average work.

The original way of straightening plates was to lay them on a surface plate and hammer them cold, and there is still no better way known of securing absolute flatness. Surface plates should be of the toughest cast-iron with a hard surface (chilling is not invariably satisfactory, though eminently so with some irons) and of a good thickness—not less than 6 in. The size

will depend on the nature of the work, but will be in the neighbourhood of 6 ft. × 4 ft. The plate is laid upon the block, and a good man will quickly bring it to truth. For girder work there is no necessity to go to this

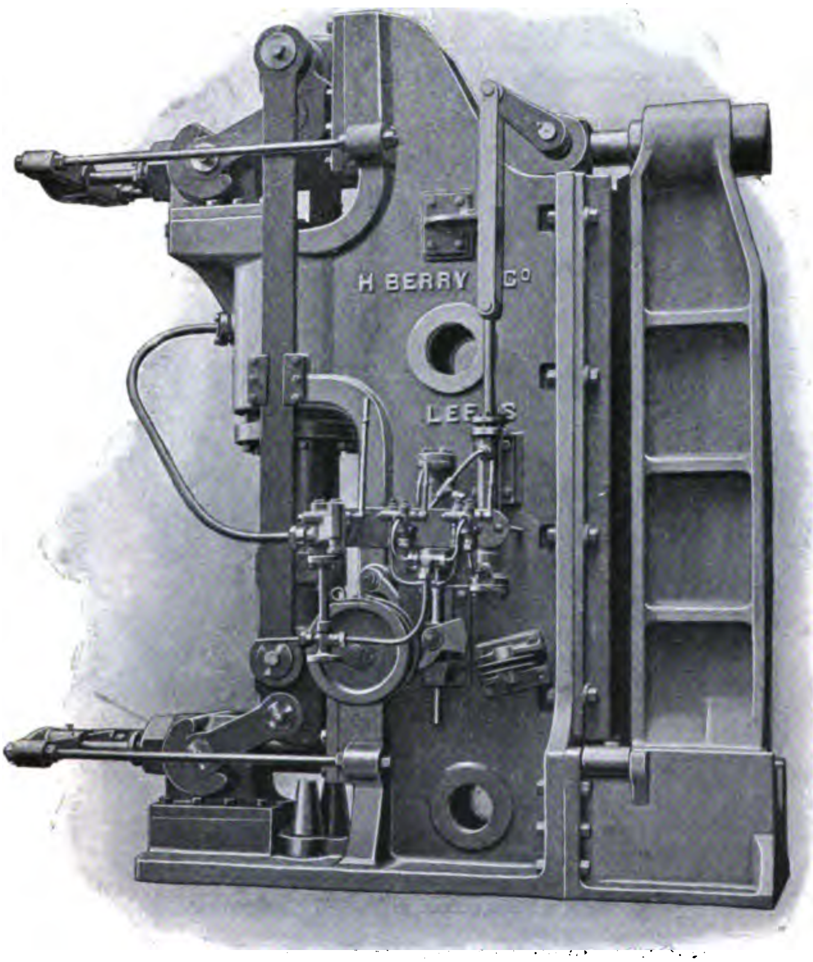


FIG. 42.—Hydraulic plate-bender.

expense; but when steel doors, etc., have to be made it is better to "cold flat" than to have the inspector reject them because they are in wind. If these blocks have much work to do it is astonishing how quickly—comparatively—they wear out, especially if the metal is not good. Perfect homogeneity is an essential, or they quickly get into hollows.

Just as plates used to be straightened by hand, so was sectional material. Angles, channels, tees, etc., were placed across a cast-iron hollowed block and struck with the sledge in various places until they came straight. Until quite recently this was the general practice; it was fairly quick so long as the sections were small, was satisfactory, and did not demand skilled labour. The first attempt to employ tools was the hand-power press shown in fig. 43. Its action is evident and it still possesses the merit of simplicity and low initial cost. As sections grew in size and got stiffer, the tool soon proved

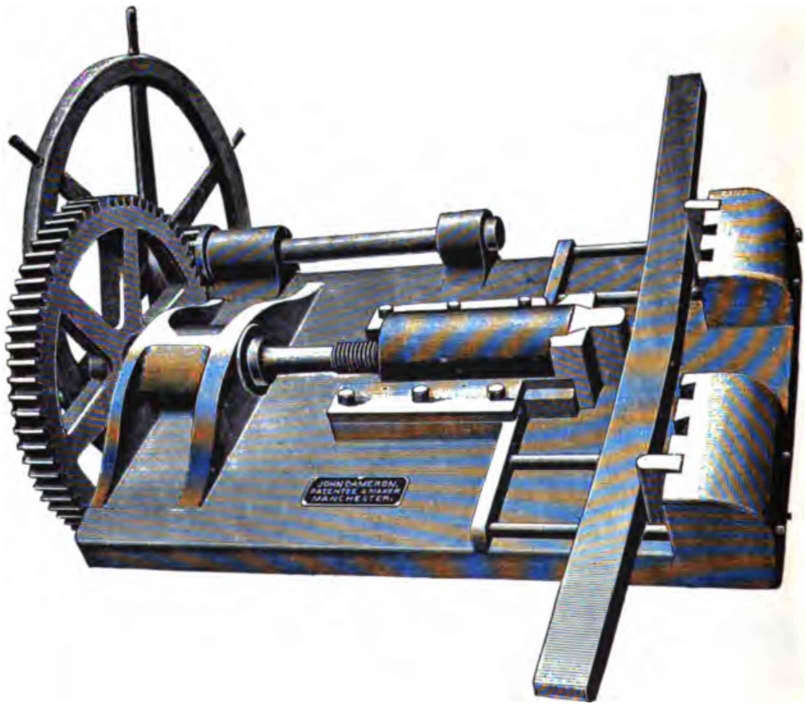


FIG. 43.—Hand-press for bending.

itself an advance on the sledge, and it still does good service in many yards. But the continued growth of sections demanded more powerful tools, and the power-bender shown in fig. 44 was evolved, and was quickly followed by the hydraulic-press arrangement of fig. 45. These two tools are to-day the standard, and many improvements have rendered them highly efficient and very satisfactory in working. Fig. 44 is geared and belt or electric driven, making from thirty to sixty positive strokes per minute, the intensity of which is under the control of the operator, the hand-wheel providing a ready and delicate adjustment. The hydraulic machine is not quite so quick, but is more powerful, and specially suitable for the heaviest sections of joists and

channels. It should have a quick power return and be capable of being managed through the agency of one handle.

For very light sections the hammer is still the best; for medium and all

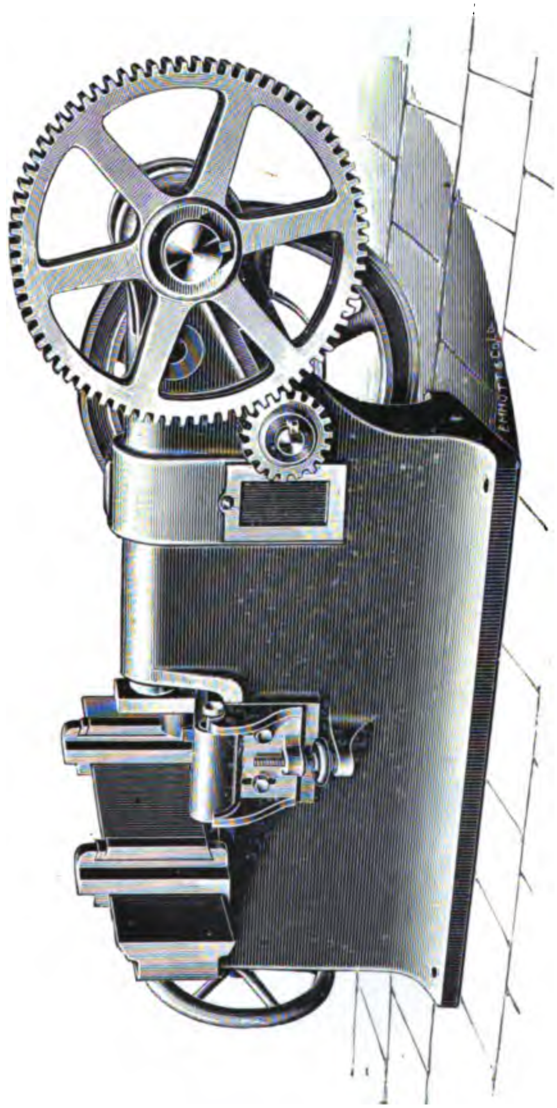


Fig. 44.—Power-bender.

angle and tee sections up to 6 in. × 6 in. × $\frac{5}{8}$-in. the geared machine is generally in use; for all heavy work there is nothing to beat hydraulics. Shops engaged on light work will depend on the first two; a general trade

will require all three. One geared and one hydraulic straightener will be sufficient for an output of 4000 to 5000 tons per annum. The hand-screw machine is not often bought now, but it is exceedingly handy and very suit-

FIG. 45.—Hydraulic press for bending.

able for those shops which occasionally do a little steelwork; for everyday and all-day use it is too slow and tiring. All machines act on the same principle—a central movable ram forcing the bar to bend between two projections on a fixed head. Of course they bend material just as easily as they straighten out, and all angles, tees, etc., which have to be bent cold

are done upon them. Bending is a longer job than straightening, especially if there happens to be two or three centres to the curve; a great deal depends on the man in charge—one who is able to "humour" the machine will get two and three times the amount of work out of it as another who is clumsy and lacks "gumption." A quick stroke and a light pressure repeated two or three times is better than a heavy single stroke for most forms of bending. For work on site of erection where power tools cannot be used, the primitive "Jim Crow" is still the best-known means. Fig. 46 illustrates this. It can be used in almost any situation where a man can get, and its bending powers are undoubted. In fact, there are few shops to-day without one or more—it is such a useful auxiliary tool. A handy extra bender when required at any time can be made from a common hydraulic jack laid flat on any suitable table and secured so that the body cannot move. A couple of stops fastened down at a foot or more apart, either side the head of the ram,

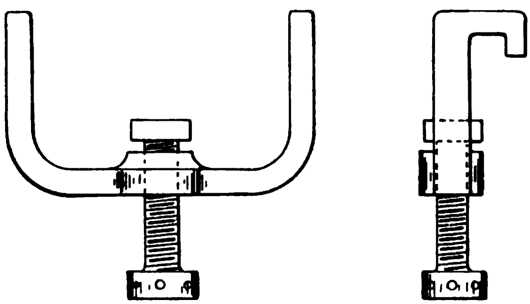


FIG. 46.—"Jim Crow."

will hold the material in place. The work is slow, but it will be good, and the tool is not to be despised. Many other similar applications for particular work will occur to the reader.

The straightening will generally be in the hands of a leading man, who will be responsible for seeing that every piece coming into the works is properly straightened before use; if the works are large, two men may share the responsibility, one taking the plates, the other the sectional material. The remainder of the men will be labourers, the leading hands working with them and being paid a slightly higher wage, or taking the whole on a piecework basis of so much per ton and paying their own labour.

Plates are passed through the rolls two or three times according to their condition, being supported and carried on trestles with roller tops, or partly by these and partly by chain slings from convenient runners. There should always be plenty of light cranes at the rolls, or else the labour cost is bound to be high. There will not be any great weights to be carried; probably the average weight of the plates rolled will be, perhaps, 5 to 7 or 8 cwts. and less, and for these quick-acting pneumatic hoists on suspended runners, or even good blocks, will be as handy as anything. They should be supple-

mented by a couple of light cranes capable of lifting, say, 30 cwts., to deal with the heaviest plates which may be used. Long narrow flange plates are the most awkward to deal with; they whip and bend so much that they must be lifted and handled in several places, and regard must be had to this when laying out plant.

Sectional material is usually much stiffer than plates, and in so far is more easily handled. Light runner lifts and plenty of trestles are quite the best means of dealing with it, with a heavier crane to lift and manage heavy joists.

If tackle is good and works freely and easily, no more than three men will be required for either plates or sections. If, however, the tools are not conveniently placed and the tackle is inadequate, more labour will be required. In some works half a dozen or more men may be seen struggling with long bars, all for the want of a little thought and outlay. Arrangements should be made so that the minimum of manual lifting will be necessary—the principal work of the men engaged being that of selection of the material and guiding of the tackle. As the steel is straightened it should be properly put down and laid out, each job by itself, so that just what is wanted next can be fetched away at once for the further operations.

CHAPTER XV.

THE GIRDER SHOP—II.

When straightened, the next operation for the plates will be planing, and this is where flats and sectional material score so heavily. Planing is an *extra* operation, involving added handling and moving from place to place, besides the actual time spent on the machines. Proper facilities for lifting and carrying do much to lessen costs, but given the most perfect known devices the operation still remains an extra one, and as such must to some extent influence prices.

Planing machines remain much as they have been for some years past, except that they have grown in length of bed and in power and general handiness. The type remains very much the same, and figs. 47 and 48 show the two styles principally in use, the only real difference being that fig. 48 has a cast-iron frame, bed, and girder, whilst fig. 47 has a cast-iron frame and bed with a steel or wrought-iron girder. For the shorter lengths of bed there is nothing to choose between them, but the steel girder type is the best for long beds, being both lighter and stronger. Different makers vary their patterns a little, as also their stock lengths, the latter ranging from 6 ft. to 25 ft. For general work the longest length is the most economical, as a longer plate can be done without moving it; but since one planing machine is not capable of keeping even a comparatively small works going, it is best to mix the sizes, and for about 4000 to 5000 tons annual total output it would be desirable to have, say, three machines—one 9 ft., one 15 ft., and one 25 ft.; the work could then be proportioned between them. Since there is a growing tendency to use flats for flange plates, it may be possible to do with fewer planers in the future, but this number fairly represents average requirements at the present time.

In modern machines it is possible to plane the longest as well as the shortest plates on any size bed. The end standards are made open, or as shown in the drawings, set back and bent over so that the bed is perfectly open, and the plates can be moved along as that length within the capacity of the tool is finished. A 6-ft. planer will thus do a 40-ft. plate if necessary, but since each move means resetting it could hardly be described as an economical operation.

Points in a good planer are that it should have open ends; self-acting reversing carriage, reversing automatically for any length of stroke; vertical adjustment to tool-holder; attachment for planing an end at the same time as a side, at any angle; and a swivelling tool-holder for planing bevel edges.

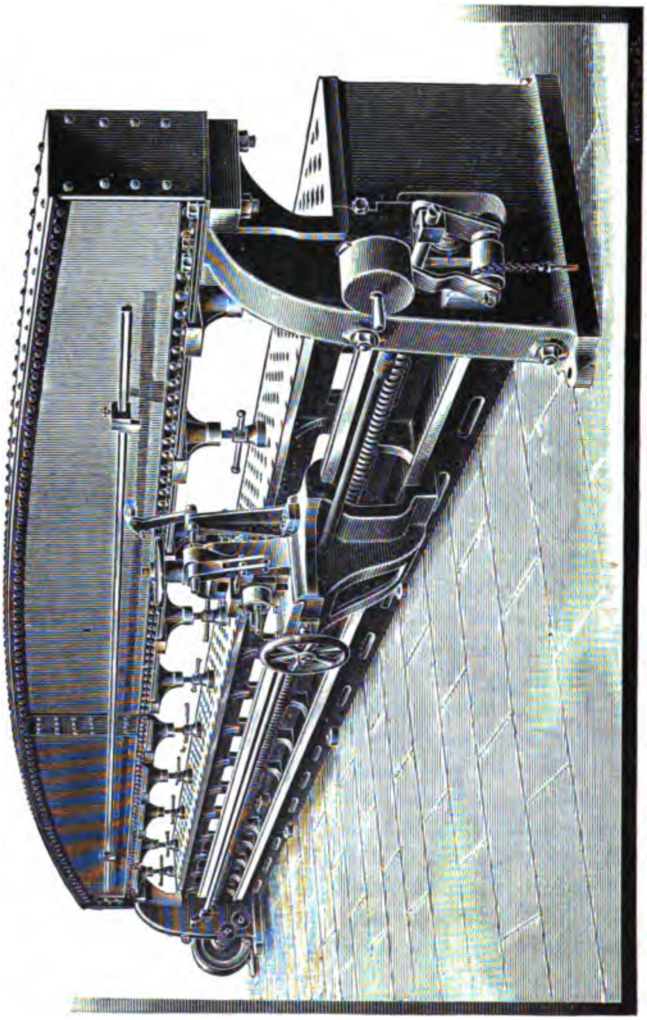


FIG. 47.—Planing machine for girder plates.

That it must also cut both ways goes without saying. A further useful provision is that the cutting tool should be made to turn over automatically at the end of each stroke, and that it should be capable of feeding down automatically when required. The latter is useful when several tiers of plates can be put in at once, as then one man could attend to a couple of

FIG. 48.—Planing machine for girder plates.

machines. It is not perhaps very often that this is done, most workmen seeming to prefer the one-plate-at-a-time rate the best; but if the work is suitable it means an immense saving in costs and should be adopted when possible.

It will be understood that the plates are clamped tight to the bed by means of the screw-jacks shown, and which can be moved along the girder as required. The carriage carries the tool and receives motion from a steel screw operated by gearing from the belt or other drive. Some makers fit a small platform on to the carriage on which the man can stand and thus be always with the tool. In place of screw-jacks, hydraulic ones are sometimes utilised. End planing attachments are not so common in this country as in America. Their success depends largely on the man concerned; for large square plates they are not much real use, since the tool has to be made to permanently take up a great deal of floor-space, and if single plates are being planed one man cannot work both end and side at their maximum rates.

Usually planing is done piecework at so much per foot-run, and the man is a superior type of labourer. No great skill is required to run the tools—the setting of the plates is the chief thing to do. Permanent gauges for different widths are very useful and should be made for all machines. Some rule-work will have to be done, but it should be made as little as possible.

As with other tools, the methods of handling the plates should be as good as can be devised. Unless a lot of shop labourers are to be kept this is a necessity. With only one man to a machine, unless the tackle is thoroughly up to date, extra help will always be wanted. The same plates which go through the straightening rolls have to go on the planers, and common sense tells us that they will not place themselves on the beds. The business of putting plates on and off is far more serious than the actual work upon them. A good, well-made tool does not take many minutes to do one side of even a 25-ft. long plate if at one setting, whereas such a plate will in some places take half an hour to get to the machine and be placed properly on the bed. Good overhead tackle similar to that described for the straightening rolls is an essential.

Whilst the plates have been going through the planing process, the sectional material has been cut off to its proper lengths, partly by the cold saws and partly by the angle and plate croppers or shears. It will be remembered that most of the short lengths of angles, for instance, were ordered in long lengths, and these must be cut up and the others brought to their proper exact dimensions. Before cold saws came into general use, such materials as channels, joists, and zeds could not be cut cold in the girder shop; the only way was to get them from the mills as near to size as possible, and then trim them up in the blacksmith's fire, afterwards filing or chipping up—a long and unprofitable job. With the advent of the saw a radical change was effected; they could now be cut in any lengths and at any angle desired,

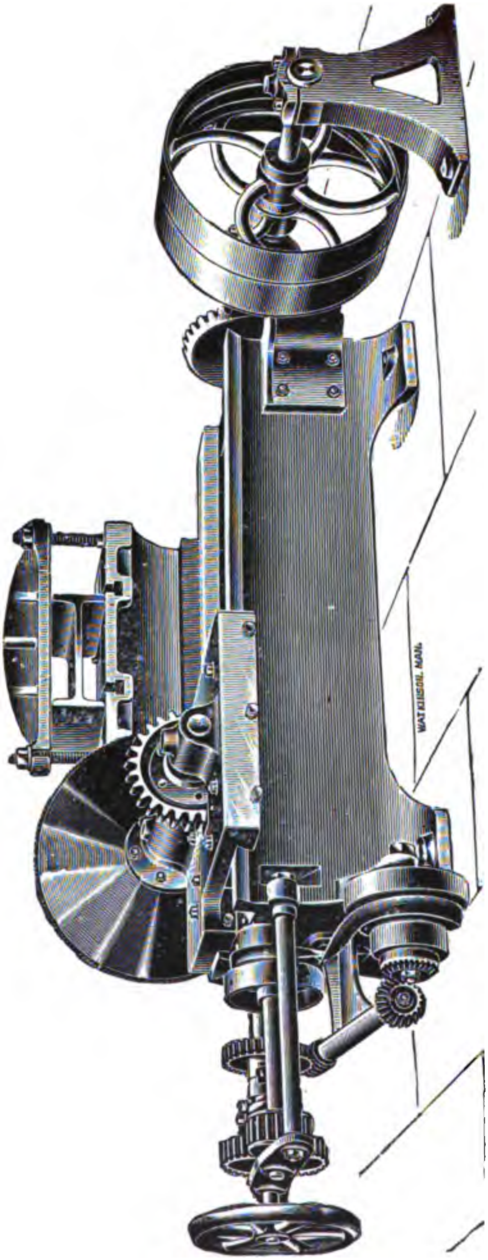


FIG. 49.—Cold circular saw.

whilst the resulting faces were so good as not to even need the file. Angle shears were early made, and though it was possible to arrange them so that they would shear in the middle of long lengths, yet this was not satisfactory; one end would be fairly clean, but the other would be bruised and require a little more cropped off it. So that, for all forms of sectional material, cold

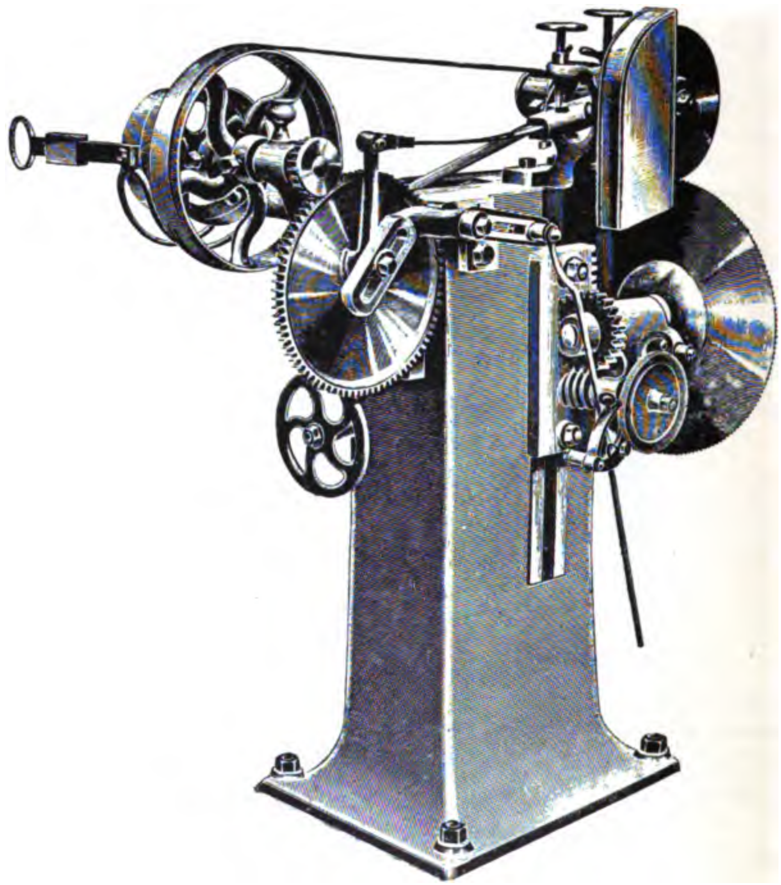


FIG. 50.—Automatic saw-sharpening machine.

saws have proved eminently satisfactory. They are, perhaps, or so appear, rather slow in operation—they do not cut through the steel in the same way as a hand-saw goes through wood; but there is no comparison between the time now taken to make a good job and that necessary before they were introduced.

There are many types of cold circular saws, though the principle of them all is the same. Fig. 49 will show the lines on which they are built. The saw

proper is circular, and from 12 in. to 36 in. in diameter; the teeth work without set, the saw being thinned towards its spindle so as to allow clearance, and it usually rotates in an oil-bath. Automatic travel is fitted, which can be controlled by friction plates, the drive being by worm gear. The work is fastened in position by bridge clamps which allow of it being placed at any angle. The table is small, so that long bars must be carried by trestles; in fact, any bar which projects over it should be supported. The saws are

FIG. 51.—Power hack-saw for small sections.

sharpened in automatic machines designed for the purpose, one of which is shown in fig. 50; an emery-wheel of the right shape is constantly spinning, and is brought down on each tooth in turn as the ratchet gear works the saw gradually round. The little machines are very effective and economical in use. Circular saws will cut any section of material, from the smallest round or angle up to the largest joist or channel within the capacity of the saw. Since the saw spindle is placed well below the level of the bed, a 12-in. saw will not cut heavy sections, and for general purposes the larger ones are preferable.

For cutting small rounds, squares, or flats, the jig or power hack-saws are very useful. One is shown at fig. 51, and the makers often claim they will deal successfully with rounds up to 4-in. and $4\frac{1}{2}$-in. diameters. Given time, they will cut angles, joists, and channels fairly successfully, but owing to their light build they are not a commercial success on heavy work; they are looked upon as being fitted for occasional rather than for constant service. The saws are used until they give out, when they are thrown away and fresh ones substituted—it does not pay to attempt to sharpen them, new ones being cheaper.

Both the circular and hack saws can be attended to by youths, given personal oversight by the foreman; and one youth can manage two cold saws and a sharpener, or three hacks, provided the lifting tackle is good and convenient. One machine can be set going and another attended to whilst the first is cutting, and so on. This makes the process cheap, and in labour cost it compares most favourably with any other method. Most shops have the boys on piecework at so much per cut whenever possible—the price depending on the size of the material.

With the output being limited, a fair quantity of saws are required for any tonnage turnover. If the ends of all stiffeners are sawn besides the general parting and truing up, one circular saw for every thousand tons of average output will barely be sufficient—some places requiring nearly two saws per thousand tons. Power hacks may be added as found convenient and necessary. Fortunately, saws are not so terribly expensive as straightening or planing machines, and a gang of them may be put down for a very moderate outlay. Efficient work again, as always, depends on the overhead tackle provided; and it is of small use putting down saws unless this is properly designed. Overhead runners and light cranes are by far the best, and should not be stinted.

Angle and plate croppers or shears are made in a large variety of patterns. Figs. 52 and 53 illustrate two typical machines. The plate shears have usually blades about 16 in. wide, placed at such an angle that long bars will clear the gap of the machine. The angle shears on the other end will crop angles up to $4\frac{1}{2}$ in. $\times$ $4\frac{1}{2}$ in., or sometimes 5 in. $\times$ 5 in.; they also are placed at an angle to facilitate the cutting of long lengths. The surfaces resulting from shearing are not absolutely clean, as in the case of the cold saw, and whilst presentable enough for most purposes they will not make good butt joints, and must be cleaned up with file and chisel. Notwithstanding this, the operation of cutting is so quick that the finished cost for cropping ends is cheaper than by sawing, the limitation being that angles and bars are the only sections which can be so treated. Dead lengths are not so easy to cut on the shears as on the saw, though much depends on the personal skill of the workman, and, as just stated, after shearing they must be filed to suit.

There are many combinations in these tools offered to the purchaser. Some have two working ends, some three, and some four; they are all variations of bar and angle shears and punches, but except for very small establishments more than two working ends are not recommended. Men are

apt to get in each other's way, besides which the neighbourhood of the tool will get congested with different work, which will more or less get mixed together, and thus confusion arises. To be of real service in a medium or

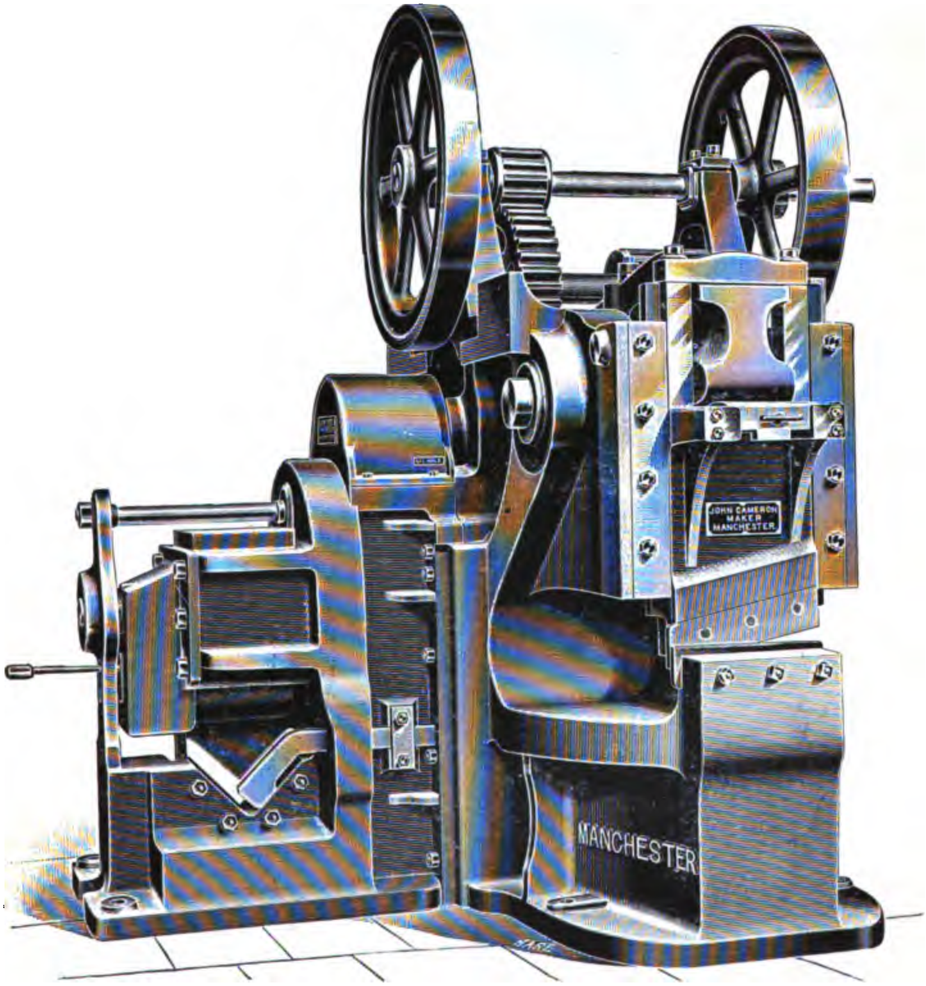


FIG. 52.—Angle and plate shears.

large sized establishment, plenty of space around the tool should be available, and the best combination is to have plate or bar shears at the ends and angle shears at the side, as in fig. 52. Small yards with limited space may find it wise to adopt three or four working ends, but only if the work is of an intermittent character and not more than any two ends required in

service at the same moment. Tools with small cranes mounted in convenient position are an acquisition in some circumstances. They will not be of much service if the general overhead lifting tackle of the shop is well designed; but

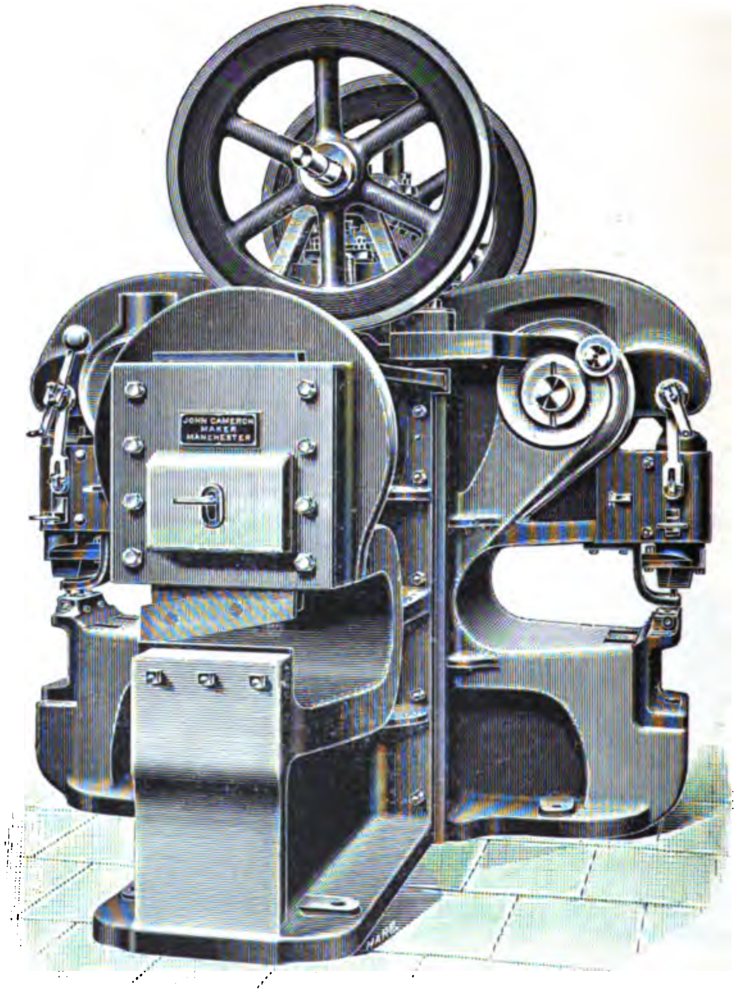


FIG. 58.—Combination shears and punch.

when a tool has to be placed in an awkward spot, or for some reasons the ordinary tackle cannot be properly brought to it, they are distinctly of use.

Up to within a very short time ago channels and joists of all sections could only be cut either hot, with the set, or by the cold saw; but a new tool has been recently specially designed and introduced for the purpose, and seems to

have a sphere of usefulness before it. Fig. 54 illustrates it very well. It is really a new type of shearing machine, or rather a combination of a punching and shearing machine, since it takes out a piece as thick as its blades when dividing a joist into lengths. The motion is intermittent and communicated by a ratchet arrangement, the blades punching or shearing out a little at each stroke until the operation is concluded. It is extremely powerful and gives a good clean cut, quite equal to ordinary work without

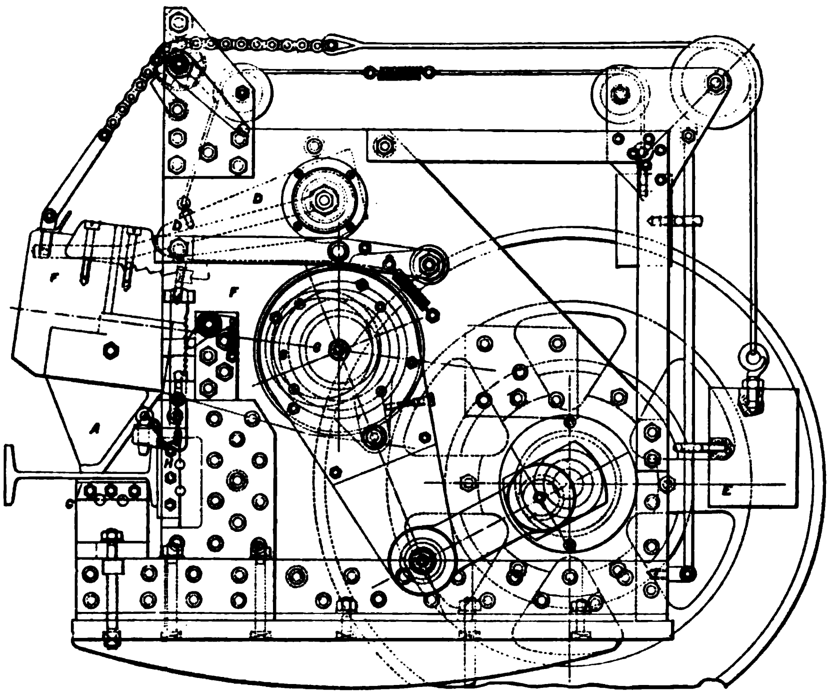


Fig. 54.—Joist shearing machine.

further dressing. Half the joist is sheared at once and then turned round for the other half.

Independent angle croppers are extremely useful in large shops, or in those places doing a quantity of similar work. They can be made exceedingly compact, and to take any size angle up to the largest they are designed for. Usually they do not take more than a 4-in. x 4-in., and are often made to take 3-in. x 3-in. and less. Fig. 55 will show their general design.

Many shops have small power croppers for flats and plates, which are kept constantly running at a fairly quick speed, and are exceedingly useful for trimming small connecting plates or links, cutting bars to sizes, etc. (see fig. 56). They take up very little room, and will often save much running

to the larger tools when placed in handy situations. They are only for small work such as can be carried to them by hand, and there is therefore no need for them to be placed under the shop transporting system.

Reverting again to jig-frame or hack saws, a tool mounting two saws which are placed to work either side a large channel or joist, cutting until they meet each other, has been put on the market quite recently. It is shown in fig. 57, and its construction will be readily seen. It is ingenious,

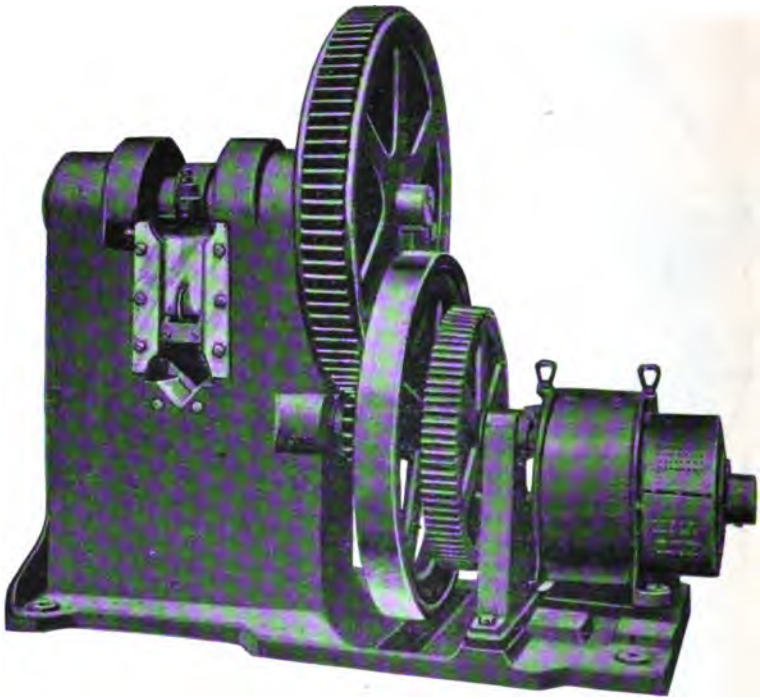


FIG. 55.—Angle cropper.

one saw being made to automatically cease cutting when near the centre, the other finishing the work.

It would be possible to notice numerous different ideas and tools which have at various times been brought out and met with more or less success; the purpose of these chapters is not, however, to show everything which has ever been thought of, but only those tools which are recognised as being necessary and desirable for the proper carrying out of the modern forms of constructional steelwork, and which have gained their place in the estimation of manufacturers either by their long-proved service or their unquestioned superiority over older methods.

It has been explained in another chapter that all plates have a slight

allowance made for planing—usually $\frac{1}{8}$-in. all round, but that sectional material is supposed to come to the works in nett ordered lengths. By "sectional" material is meant practically all forms and shapes except plates—angles, flats, tees, zeds, channels, joists, etc. The allowance on the plates

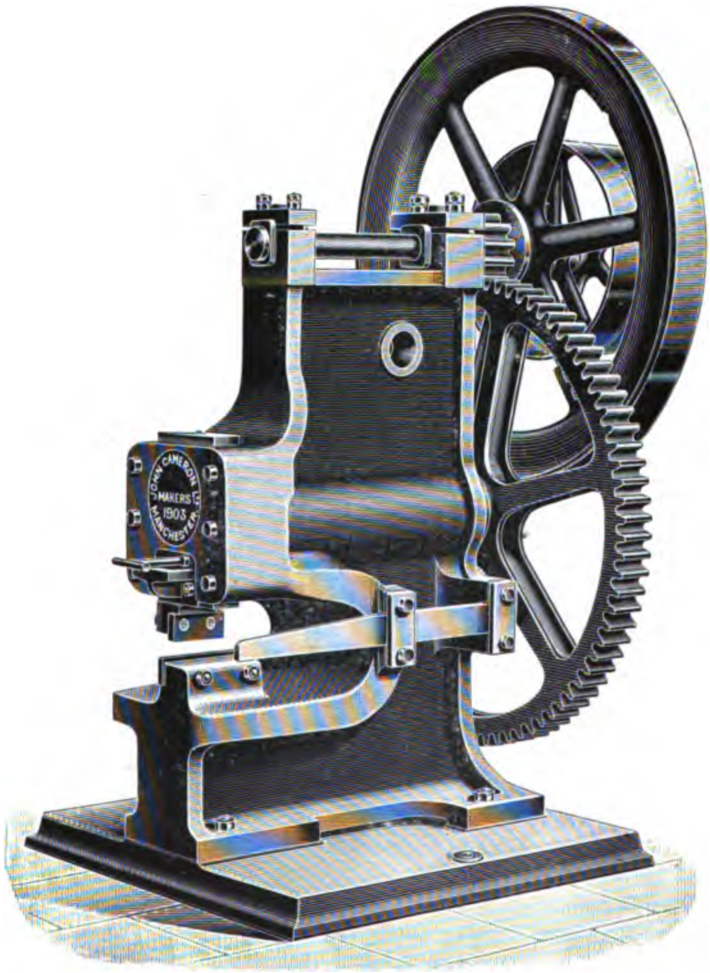


FIG. 56.—Small cropper for flats and plates.

is taken off by the planers, and the slight extra lengths which cannot be avoided on the sectional material by the saws or shears, as the case may be, and the material properly reduced to lengths and sizes before going further. There are one or two exceptions to this rule which will be noticed in another

place, but it may be taken that for most work, and for all heavy and good work, this is the usual course.

Now comes the marking-off. There are three methods in common use for this; the employment of the thin tube dipped in whiting, the centre-punch, and a combination of the two. The first is perhaps the quickest and the last the slowest, but unquestionably the better job lies with the last. The templates should have all holes in them of the proper size, *i.e.*, the size the

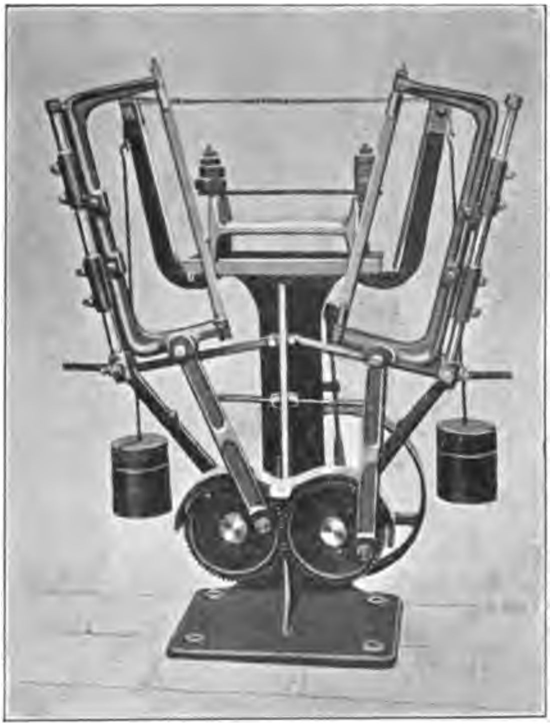


FIG. 57.—Double hack-saw.

holes should finish at—not in any way because the exact dimension affects to any degree the exact finished size in the steel, but as a guide to everyone concerned, and because there is no good reason why they should not be so arranged. Changes in diameter should also be plainly marked upon them, so that attention cannot fail to be drawn to them; the holes being also the right size, there is then no excuse for mistakes in the shops or yard. When the whiting tube is used, a small brass tube of thin gauge, about 3 in. or 4 in. long and of the proper diameter, is selected and the ends squared. Whiting or white lead is then prepared in a thin paste, and the end of the tube dipped in and then passed through a hole in the template, and the plate marked with

the impress of the tube in white; this being repeated until all the template holes are shown on the plate in white. Then the cramps temporarily fastening the template to the plate or bar, and which are merely bent pieces of iron of U-shape, are knocked away, and the piece is ready for the punching machine. The puncher (operator) by continued practice gets very expert in sighting these marks and seldom fails to hit them correctly. At the same time mistakes occur occasionally.

In the centre-punch method, a punch of the right diameter is passed through the template holes, and on being struck by the hammer leaves a small mark or indentation in the centre of the hole. This indentation is the guide for the "nipple"-punch, as described in Chapter VIII., and it is evident that, if templates are correct and the marking-off and punching conducted with reasonable care, true holes will result even when several thicknesses come together. The only drawback is that the centre-punches on the steel are not always very easy to distinguish, and this is got over in the third method by letting boys either follow the marker-off with the white-lead tube system, or surround the dots with circles when the template has been taken away. These serve to draw attention to the centre-punch marks, and are of considerable help at the punching machine.

It is the duty of the marker-off to paint on the bars or plates particulars as to the sizes of the holes, giving specific directions to the puncher, copying them from the instructions on the template. The punching machine is not worked from a drawing, and the marker-off's instructions are the only guide the operator has. Countersunk holes have usually a ring of white paint put round them; changes in diameter are shown by figures, lines, and arrows, or other hieroglyphics—most shops having their own language in this respect.

When work has to be punched and reamed, the templates should have the punched sized holes in them, so that there may be no mistake in marking-off and punching. It will be the plater's duty to see that after this operation they are sent to the drilling gangs to be made to the right finished sizes.

In some cases plates and other material cannot be marked properly to size until the templates are made, as in the case of awkward angles or bevels, etc. It is these little points which are the plater's especial care. If the piece requires a great deal of setting out he will stop it going through the planing machines, by looking for it and setting it aside so soon as it comes into the shops; it would be no use planing a rectangular plate all round and then shaping it entirely differently afterwards. At the same time, if the alteration is not much it can be planed in the regular way; everything will depend on what has to be done. From the construction of planing machines it will be seen that they can only work in a straight line—they cannot be used for curved surfaces; so that if it is curved web plates which are required, say for a solid-web arch girder, time spent in planing would be lost, as the whole of the planed edges would have to be cut away again. If, however, it is an odd flange plate or two, which will require cutting on the angle at one end only, there is no need to interfere with the normal course; it will upset

matters much less to send the plate back to a small planer for the end only to be done, when the templates have come through.

Curved girders give a great deal of trouble in the shops. As just noted, the webs cannot be planed, but they have to be brought to size somehow. Very often the girder suffers because the strict depth of web is not kept throughout by reason of this extra work. It is a temptation to roughly punch or shear it out a little under size, so that it will allow the flanges to sit properly; when once the girder is together, such a course could not be detected, and if rivet-holes are dangerously near the edge the fact will not be apparent. There are no tools by which any given sweep or curve can be cut mathematically correctly except the hammer, chisel, and file. It would not pay to instal a machine tool even if one could be found—it would not be at work a quarter of its time. The only way at present open is to mark the plates out from the templates and to either punch or shear (whichever happens to be most convenient) as much of the surplus material away as possible, and then dress the plate to proper size by hand. If a pneumatic plant has been

FIG. 58.—Pneumatic chisel.

installed, the pneumatic chisel will prove a great help. It is many times quicker than the hand hammer or set and flogging hammer method. Fig. 58 will illustrate a type, and it is not too much to say that their introduction has revolutionised all chipping processes. The hammer proper is shown, and it operates by an internal piston rapidly hitting a chisel which is loosely inserted in the left-hand end, by the agency of compressed air brought to the hammer by means of a pipe fastened on the small nozzle seen underneath the handle. The trigger on the top of the handle is the air-regulator. These tools are exceedingly handy in the girder shops for all forms of chipping and effect a big saving over old methods; two or three of them should be found in every shop. Not only do they cut rapidly, but they take a very much larger cut than can be attempted by a hand-chisel or even the set. For heavy work this latter tool used to be in general use before pneumatic hammers were available. It is merely a short stiff chisel held by means of a piece of $\frac{1}{4}$-in. or $\frac{3}{8}$-in. iron or supple wood, which is wrapped around it in a recess near the head, and the two ends of which are held in the hand, being 18 in. to 2 ft. long. By means of this handle the set is held in position and is struck with a flogging or striking hammer. Two men are needed, but with a good striker fairly rapid progress may be made.

Marking-off should be done on proper tables, which should be placed conveniently near the planing machines so as to lessen the carrying about. It is not economical to throw plates down anywhere when they are planed, to pull out the ones wanted, and to clamp on the templates in whatever position they may happen to be lying. It is a slipshod, careless way of working, and one which is bound to result in errors and slips occasionally. Men cannot work either well or expeditiously under cramping or trying circumstances, and it will pay a hundred-fold to lay the plates and other material out at a reasonable height above the ground. There is no need to go to any great expense with the tables; cast-iron chairs about 24 in. high carrying old rails make the best trestles which can be had, and they can be covered with old boiler plate or stock or wasters as they are made, for every place, no matter how well conducted, must occasionally make mistakes. There is no gain in making them very wide; enough width for men to work on either side is all that is necessary, whilst there is nothing lost if they are of no more width than will allow of working one side only at a time. The great essential is that there shall be no lack of lifting tackle; runners overhead and light cranes must not be spared, and the outlay will never be regretted. The tables are best suited to marking out plates and flats; sectional material is better on the bare trestles; being stiff enough to support itself, it can be got at better this way, besides being much easier to handle. It is surprising how quickly marking-off may be done with a little practice. It is only labourers' and boys' work, but they get wonderfully expert at it, and a small gang will keep quite a fair-sized shop going well. The work is all at day rates, and it therefore pays the foreman to look in at it frequently.

The next step is the punching, and for this we have a variety of machines ranging from the old horizontal long-lever punches to the newest vertical types. There is perhaps a greater variety of these tools made than any other; they are single-ended or combined with each other, with plate or bar shears, or with angle shears in an immense range of patterns. They are to be had belt-driven, steam, electric, hydraulic, or pneumatic, as preferred; in fact, ingenuity seems to have gone mad in trying different methods and combinations. It is quite difficult to buy a set of shears without them having a punch coupled on somewhere; the craze for conserving power by making machines for a multitude of purposes has flooded our markets and shops with clever mechanical contrivances which are marvels of *multum in parvo*, and very often not much else. The proper sphere for the combination tool is the small shop; the large works has room in which to put down machines which will keep operations distinct and men out of each other's way. It is not always economy to make as much use of one motion as possible; economy often steps out when one motion is made into a variety of uses. The utmost possible single use of any motion is the economy required in a large place. When buying machines the maker will often point out that for a trifle extra a given tool, say a punch, can have a pair of angle shears added; thus the one tool will serve two purposes and cost considerably less than two

separate ones. This is quite correct; capital expenditure will be much lower by such a course being adopted. Now comes the other side to the question. What sort of work is going to be done and what is the size of the shop? If

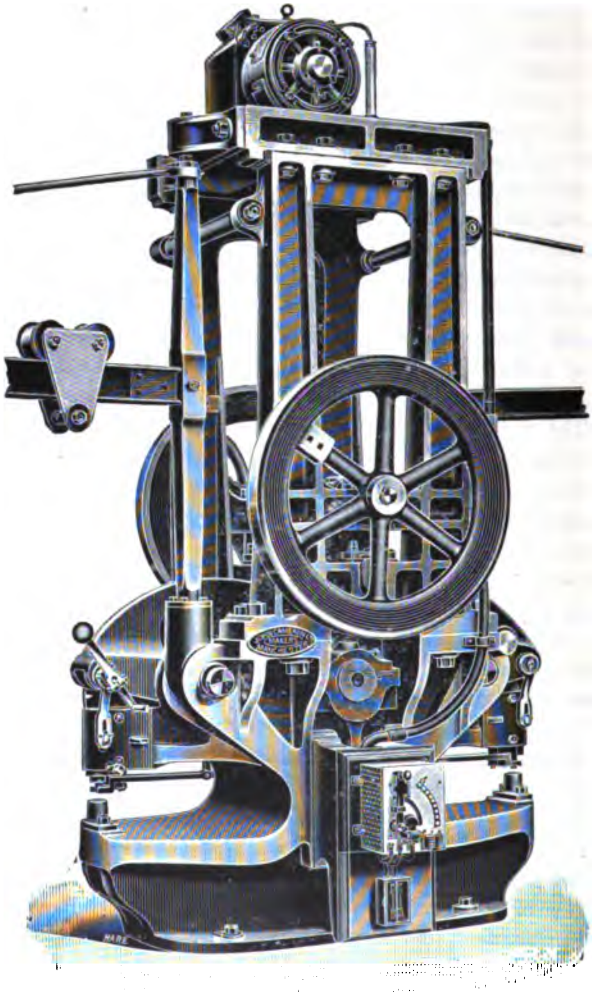


FIG. 59.—Electrically-driven double-ended punching-press.

the work will be miscellaneous because the shop is small, and it would be impossible to keep the punch going all day, by all means combine the two so that the maximum of work can be got out of the machine. But if the shop is large, so that not only one but several punches will be kept going all day and every day, have nothing to do with combinations of this sort. One

operation in one place must be the aim if cheap work is desired; a little capital saved in tools will mean a big current expenditure.

Figs. 59 and 60 show double and single ended punching presses of a well-known type; fig. 59 is shown electric and fig. 60 belt driven. Either or both may be operated by belt or motor or be direct steam-driven as preferred. Fig.

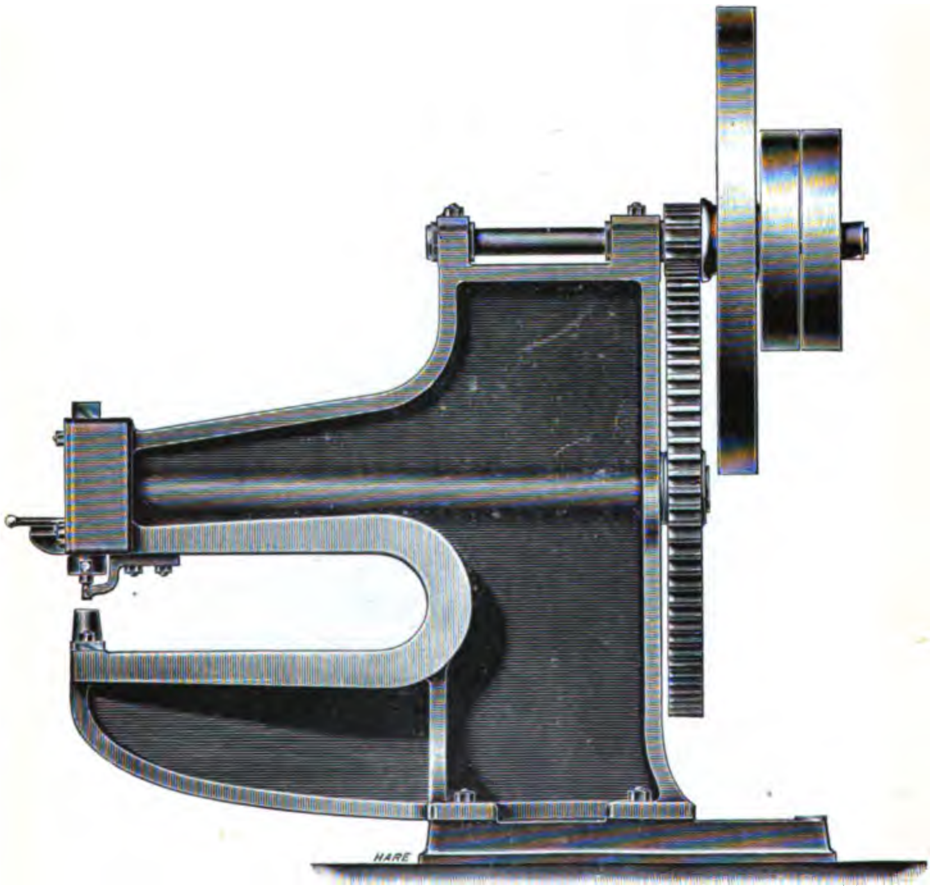


FIG. 60.—Belt-driven punching press.

61 shows a hydraulic punching press; figs. 62, 63, and 64 illustrate a few out of the many obtainable types, each one of which is claimed to have some point of specific superiority. In a large works different-sized machines would be selected. Thus there would be no use in having, say, a number of the heaviest type with a gap of 48 in. and to punch $1\frac{3}{4}$ in. out of $1\frac{3}{4}$ in. Such a machine is more suited to a shipyard than to a girder shop. At least one

tool would need a big gap, so that it could take the largest plates, but much smaller gaps would do for the others. For instance, what is the largest size gap which would be required in punching sectional material? The largest commercial joist which is in use is the $20 \times 7\frac{1}{2}$; an 18-in. gap would take this well without the necessity of turning over. But angles and tees, of which there are by far the most to be punched, would be well accommodated with a horizontal machine, as in fig. 64, so far as gap goes. According to the

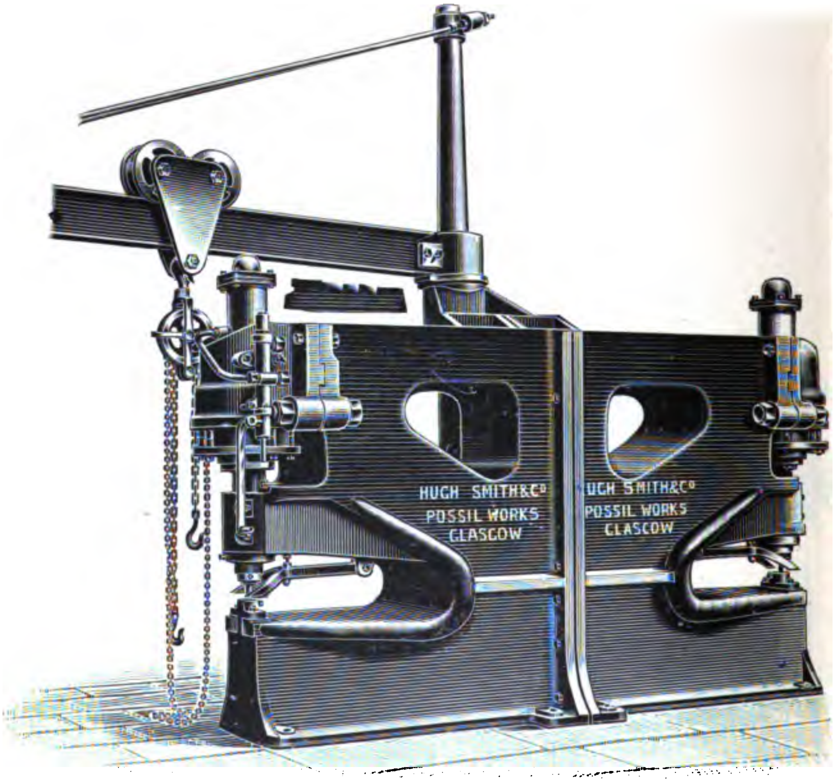


FIG. 61.—Hydraulic punching press.

size of the works would the machines be chosen. For a large place three or four different sizes would be the best. Machines can be bought with gaps varying from 72 in. to 12 in., and to punch to almost any requirement, so that as great or small a range can be obtained as considered desirable for the work to be done.

Lever machines are by far the most common and, on the whole, the most satisfactory. There are at least fifty lever to one hydraulic or other system. It must be admitted that the most popular is also by far the oldest, and that the hydraulic has been badly handicapped in starting; at the same time, lever

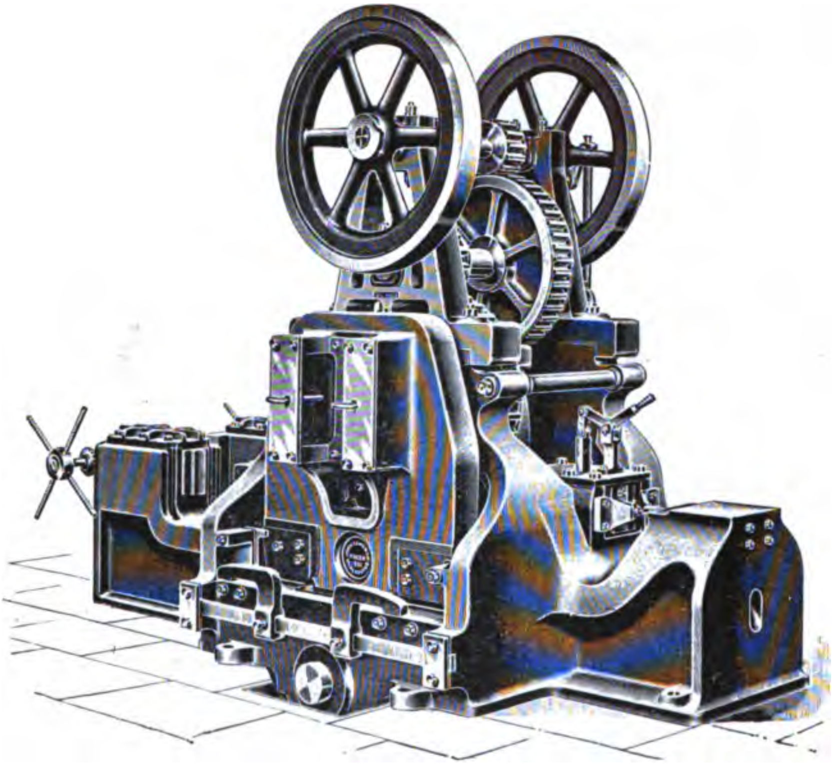


Fig. 62.—Combined punching, bending, and angle-shearing machine.

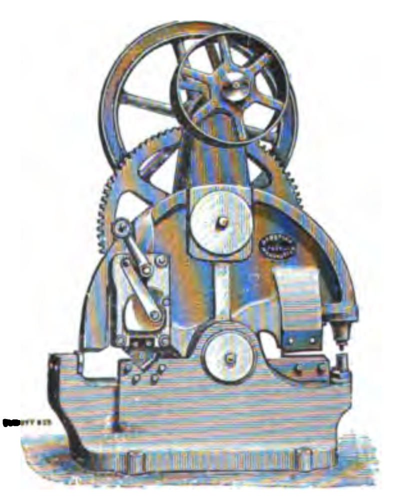


Fig. 63.—Combined punching, cropping, and angle shearing machine.

presses forty and fifty years old are running to-day in some works, and so far as capacity for further service goes there would be no need to displace

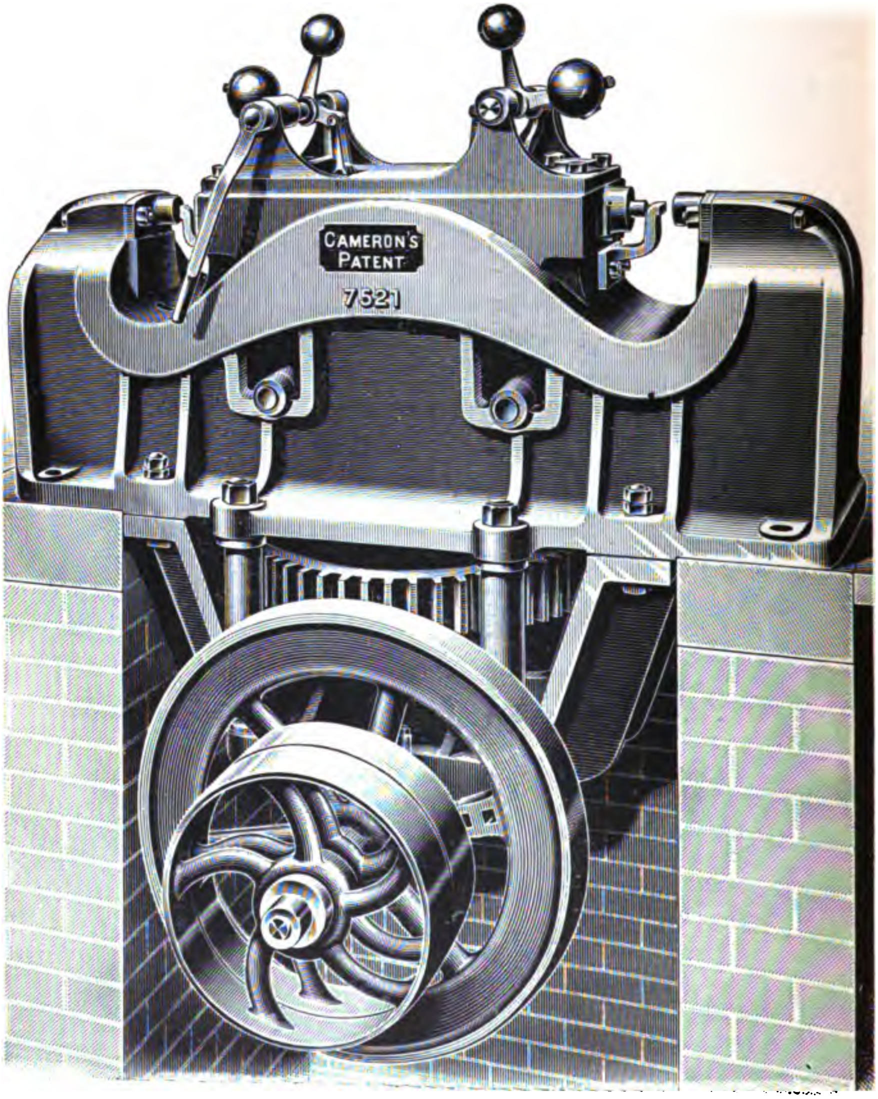


FIG. 64.—Horizontal punching press.

them; it is only that they are slow and inconvenient compared with modern designs. Presses are run any speed up to about sixty strokes per minute. This latter is fast punching and wants a smart man, but with proper foot-

control gear it is quite workable. There is, however, no room for any other operations on the same press while such work is being turned out. Hydraulic machines do not work at anything like this rate; in fact they are as a rule much slower than the lever presses; their advantage is

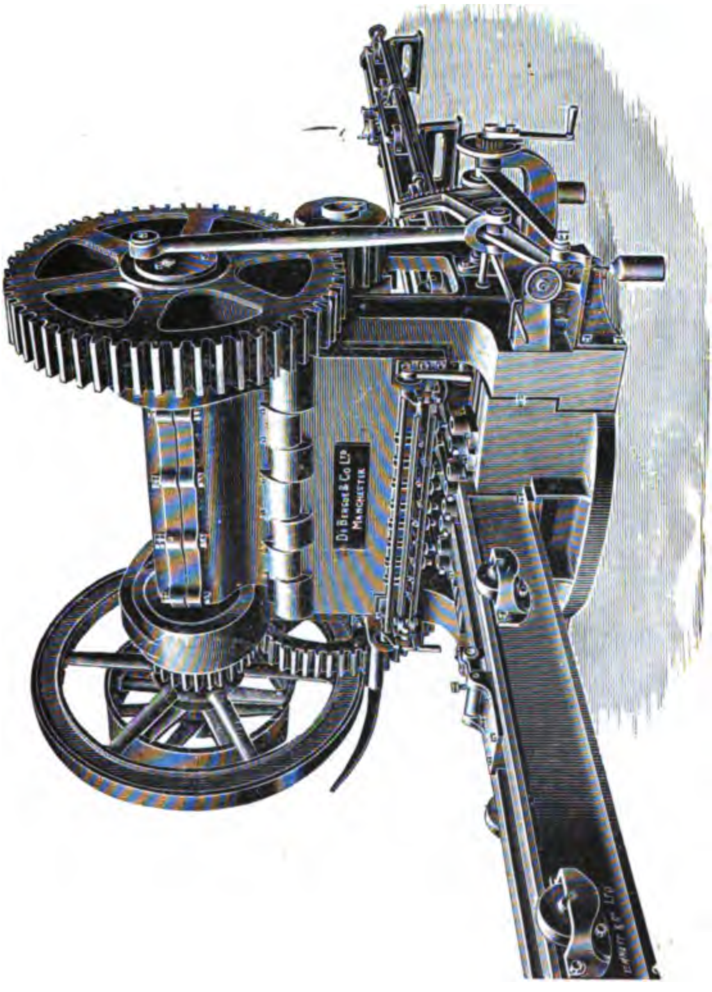


FIG. 65.—Automatic multiple-punching press.

that having no shafting they take no power when not running, and they can be placed in corners conveniently for odd holes or small occasional work during assembling.

There is nothing really new in punching presses except small conveniences; main features of design have remained the same for many years. Some long time ago fixed multiple punches were introduced; these were designed so

that two, four, six, or eight holes abreast in a plate could be punched at any desired fixed centres. Then the plate was moved along in the ordinary manner, the result being that the longitudinal pitch was determined by hand, the cross pitch coming according to the spacings of the punches. About fifteen years ago De Bergues introduced their automatic multiple-punching press, of which there are now several in British yards. This machine can punch any desired number of holes crosswise of the plate at any pitches to which the punches have been previously set; at the same time it will feed

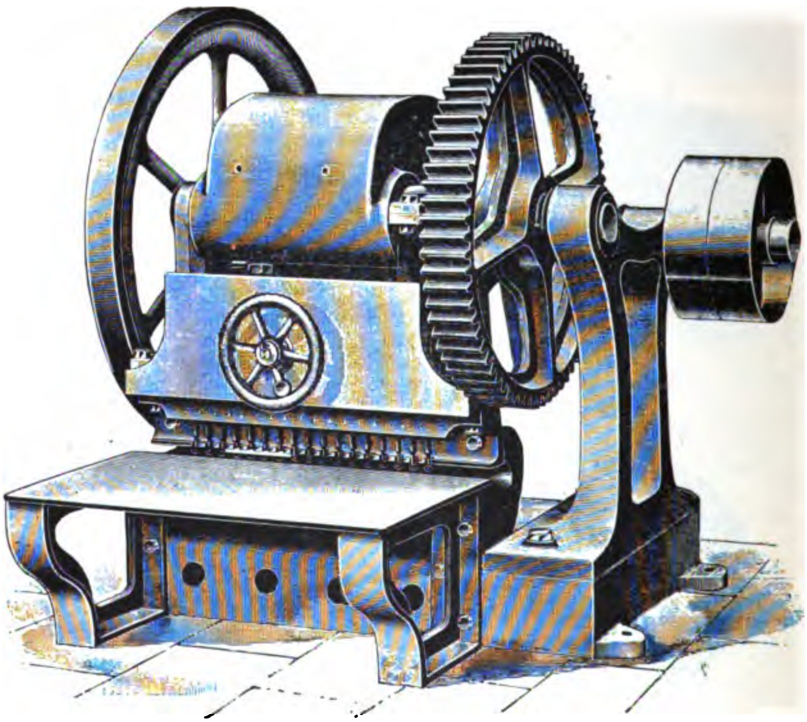


FIG. 66.—Multiple punch for tank work.

the plate through automatically at any desired pitch, putting in also odd pitches when they occur. Fig. 65 shows this tool. For repetition work which suits it, it is exceedingly economical. Some firms make the same things year in and year out to exactly the same templates, and to them such a tool is invaluable, since not only will it do the work at less than a quarter the time taken by the ordinary single press, but it dispenses with a large amount of labour also. In addition to these recommendations, there is no need to do any marking off, and this time is therefore saved as well. There are a few other such tools on the market, some of them American, notably one which will punch the webs and flanges of rolled joists at the same time,

but they are all variations of the principles of this tool. The essential to their successful employment is repetition work. If a hundred girders are to be made exactly alike, and their riveting is suitable, a very great saving is bound to result; but if each one of these girders is different then the tool will not pay to use. The repeated settings necessary and the trouble and attention it would require would quite nullify any other advantages. As it

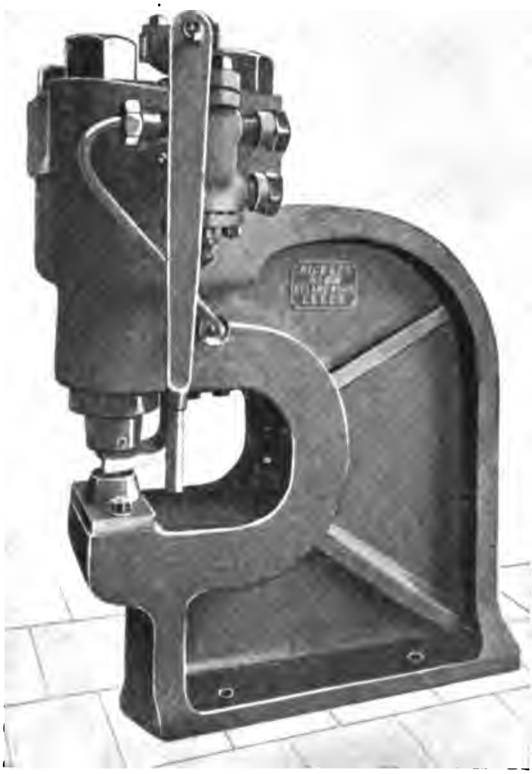


Fig. 67.—Small hydraulic punching machine.

is necessarily very expensive, care would have to be exercised in its purchase, since a costly tool requires a great deal of work to make it pay interest on outlay. It is always possible also, with a little ingenuity, to rig up special tackle to the ordinary punching press when a run of, say, pontoons or tanks has to be made. Marking-off can be done away with when a regular pitch only is required, by many devices which will occur to the engineer.

A multiple punch specially designed for tank work, or wherever single rows of holes are required, is shown in fig. 66; sixteen, twenty-four, or more holes can be punched at once in the same straight line, and at any required

pitch, since the punches may be spaced apart as desired. Such tools are especially handy for sheet-metal work, at which they excel; there is obviously a limit as to the number of large holes in thick plates which can be punched at once, and so for heavy girder work they are not of much use.

Each punching press will have its own operator, who will be rated as a skilled man, and a gang of labourers varying from two to four or five, accord-

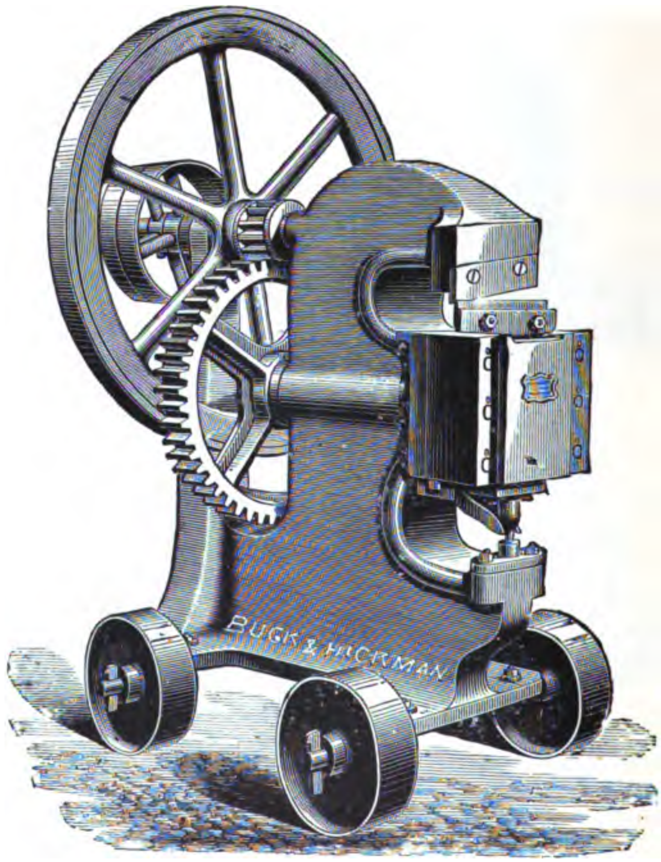


FIG. 68.—Portable punching and shearing machine.

ing to the work being done and the tackle equipment. If there is dearth of proper tackle and heavy flange or web plates are being punched, four or five men will not be too many, whilst more than that may be occasionally necessary. Big plates take a lot of handling, and it is not safe to have too little help with them. If, however, there is plenty of good overhead tackle, a couple of men will manage most that comes their way, since their main work will be to guide and not to lift and pull. There is, perhaps, nothing in

a girder yard which pays so well to instal as proper handling tackle. By its use labour costs may be cut in less than half, besides the valuable time which is bound to be saved.

The amount of work turned out by each press varies so greatly with the class being made, the tackle used, and the whole laying out of the plant, that it might be very misleading to give any figures regarding same. A fair day's

FIG. 69.—Hand-lever punching and cropping machine.

work on perfectly straightforward stuff in the average shop should, however, yield about four to six thousand holes per punch. At the same time two thousand holes might be very stiff work; whilst, again, six or seven thousand might mean no more. There are so many factors that it is difficult to offer any real guide. A great many shops put the men on piecework. The head puncher takes the work at so much per hundred holes and pays his own labour. Since the price must necessarily vary in every yard according to the average of the work done, it would be invidious to name amounts.

Very useful auxiliary tools for punching and shearing are shown in figs. 67 to 71. They are exceedingly handy for assembling in the shops or in erection on site. They are not too big or heavy to be taken about, and yet

FIG. 70.--Hand-lever punching machine.

for ordinary work they are thoroughly efficient. The engravings will speak for themselves and detailed explanation is unnecessary. It is astonishing how much work can be got from the common bear punch (fig. 71). The

tool is nothing but a common screw-thread in a suitable nut—a heavy screw-clamp in fact, but it will "bear" $\frac{1}{2}$-in. holes through $\frac{3}{8}$-in. plate with comparative ease, and larger sizes are capable of $\frac{7}{8}$-in. holes through $\frac{3}{4}$-in. plates!

Taking them all round, punching machines, whilst perhaps a little barbarous, are yet of immense service to the steelwork trade. Work can be done at prices which without them would be very heavy, and taking everything into consideration they do very satisfactory work. When it is remembered that despite the fact that most rivets are closed with pressures well over 20 tons, and that therefore the aggregate put on to rivet flange plates together is enormous, yet no account whatever is taken of friction in calculations, it will be seen that there are potent factors at work of which nothing at all is

FIG. 71.—Screw bear-punch.

recked. Take the case of the main angles of a girder closing on the webs. How many men would like to say the exact amount of bearing stress sustained by the rivets? True, it can easily be calculated—leaving friction out of account. But we all know that the calculations are actually only comparative—it is impossible to say that the rivets take the whole of this; at the same time it is not possible to say just how much they do take. We are in the dark to a very great extent; but it seems more than likely that any uncertainty which may be felt on the score of damage to the plate through punching is met and counteracted by the great pressures engendered by riveting. In any case it is not likely that the rapidity and certainty of punching will be displaced by new methods just yet, and so the commercial side of the matter may be trusted to assert itself again in its cycle, and for many classes of work we believe that punching will long remain the favoured method.

CHAPTER XVI.

THE GIRDER SHOP—III.

AFTER the punching comes the reaming or "rimering," as it is variously termed; or, in those cases where drilling through the solid is required, the punching is, of course, omitted, and the drilling follows the marking out. In both cases the tools used are the same.

There are two ways of reaming—doing it plate by plate, as in punching, or doing it when the various plates are assembled together. The first way is obviously not likely to give any better holes through a flange of several thicknesses than would punching the finished-sized hole at first; the only advantage it possesses is that it removes any damaged material caused by the punching, leaving perfectly sound metal around all the holes. This result may be to some extent an advantage, but it is of nothing like the importance of getting all holes true and lineable throughout, either theoretically or practically. It is therefore waste of money to reamer without doing it through the several thicknesses; the prime object is to give true holes: the fact that damaged metal is also removed thereby is merely an added recommendation to the process. Unless the several plates or pieces are put together, and the drills sent right through them, they might just as well—and a good deal more economically—be punched full size at once.

In most girders the majority of the holes are in the flanges, and it is of primary importance to first know how these are to be dealt with. It is seldom that a flange is so heavy or unwieldy that it cannot be put on one of the many types of drilling machines made where either all its holes can be reamed or drilled, or all those not in the "break-joint" sections of its length. To do this the plates and angles forming it must first be assembled, and the plater will collect them together and lay them out in proper order according to his drawings. Most girders for delivery in this country will be sent away from the works whole, but when for export they will either have to be divided into suitable lengths for shipment or go in their several members, or even in cases "plate small"—that is, with all the material holed and ready for putting together, but no two pieces actually riveted up. The actual method of despatch will depend entirely on the size and

weight of the girder, since shipping lengths and weights are necessarily limited. When a girder is going away whole its flange, if not too long, will be put together and taken bodily to the drills; if too long and unwieldy for this, it will be done in suitable lengths, and the few holes which are at the joints will have to be put in by hand-tools when the whole girder is assembled. The small holes put in by the punching press will come in very handily now for temporarily fastening the pieces together during the reaming. A few service bolts or drifts put in here and there will serve very well, and do away with the necessity of clamping together, as when there are no holes in the plates and drilling through the solid has to be done. The bolts are moved about in the flanges on the machines as the reaming proceeds, so as to always keep everything solid together.

Generally, flanges are thus laid out on the ground conveniently near to the drills, and if they are exceptionally large no better way can be found. If, however, they are comparatively small, a few tables for the purpose will be of assistance. It all depends on the normal character of the work as to whether such tables or trestles are worth putting up. If of a very varied description they might be more in the way than of use, whereas if of a medium tolerably similar character they might prove of great help. In many works the marking-off tables are used, and the same men who do the marking off do this assembling; but that, again, will depend entirely on the output of the place. If so much is coming through that these tables are never clear the plan is not feasible. Plenty of light overhead tackle should be available wherever it may be done. One of the most wasteful sights in a shop is to see half a dozen labourers struggling with a big plate or angle. Tackle, not muscles, is what is wanted. It is much easier to assemble a flange which has been punched small ready for reaming than one without any holes in it. The holes assist the men in laying the plates properly; bars can be inserted and slight hitches given in any desired direction; without the holes they must be lifted and eased or flogged a little with the hammer — a much more tiring job. Besides, when holes are to be reamed out there is no objection to "drifting" the plates together. Drifts are short round taper-pieces of iron or steel, usually about 6 in. or 8 in. long and with perhaps $\frac{1}{4}$-in. or $\frac{3}{8}$-in. taper in them, and of sizes corresponding to the holes for which they are to be used. They are flogged into the holes so as to draw plates together and bring the holes as fair as possible. In many specifications clauses will be found prohibiting drifting in consequence of the abuse which often goes with its use. In the old days when punched work was good enough for everybody, but the methods of setting it out were not quite so exact as now obtain, all holes which, on assembling, were not fair, but partook of the character shown in fig. 27, were forcibly drifted into shape for the rivets. Exceptionally bad cases were drilled out, but if there was any likelihood of a drift being of service one was promptly hammered in. Of course the result was to considerably injure the metal; slight projections were broken down and a way made for the rivet regardless of

anything else. It was, in fact, the common practice to precede riveting by drifting the holes, and the riveters seldom thought of putting a rivet through without first forcing a drift in—knocking one down from the top and forcing it back again from the bottom. Designing engineers gradually got suspicious of the proceeding, until it got common to prohibit it—at all events on paper. There is no question but that a certain amount of drifting is necessary when several different thicknesses come together—there is no way so certain and so handy of getting plates to take their proper positions; and when holes are to be afterwards reamed out there seems no objection to it. It is, like many other things, good in moderation and in its place, but capable of abuse at times. One of the points for the inspector to watch is that it is only used in reason; an inordinate amount of it should raise suspicion as to the accuracy of the templates used for marking off.

When put together and bolted up with service bolts the flange is ready for transference to the drills, which should be so placed that it can be lifted direct upon their beds or trolleys by the shop cranes.

These—multiples and radials—are the two standard types of drills in common use. Both are made in an infinite number of patterns and designs, but, with the exception of a very few special tools just being brought on the market, they broadly divide honours between them. Naturally the first drills to be used in steelwork were single drills, but they were obviously so slow in getting over the work that they were gradually displaced by multiples of which fig. 72 is a typical example of a modern type. Older designs had long beds on which to lay the work. Like multiple punches, there are so many drills abreast between two standards, and they can be set to any desired centres. In some machines the work is laid on the beds or trolleys and gradually led through the standards; in others the bed or trolleys are stationary and the drills are moved along. A travelling bed takes up the most shop-room, but is more satisfactory in use, since the moving heads seem more apt to wear and get untrue on their runners. Sometimes there are two or three heads to a bed, depending on the length of the latter. Each drill (there are often twelve to a head, so that two flanges can be laid side by side) can be run independently of the others, and so thrown in or out of action as required. When set, the machine both operates and feeds its drills without further attention until the holes are through, when it requires placing on the next pitch.

Some few years ago a reaction set in against multiples. As they wore they developed a trick of breaking drills, this, curiously, being coincident with the extended use of twist drills in place of the common ones. The fault was traced to wear on the feed-screws and guides allowing the drills to run a little out of the perpendicular, and, as there was no room for deviation when the drill filled the holes from top to bottom, something had to go. Perhaps one drill out of four or six would snap, the broken part remaining in the hole. The only thing to do was to put a fresh drill in and go to the next hole, leaving the bit to be got out afterwards and the hole finished by hand. This

fault was most particularly noticeable in drilling from the solid, and as mild steel came into use it was thought that the metal had something to do also with leading the drill astray, especially as new machines seemed to develop

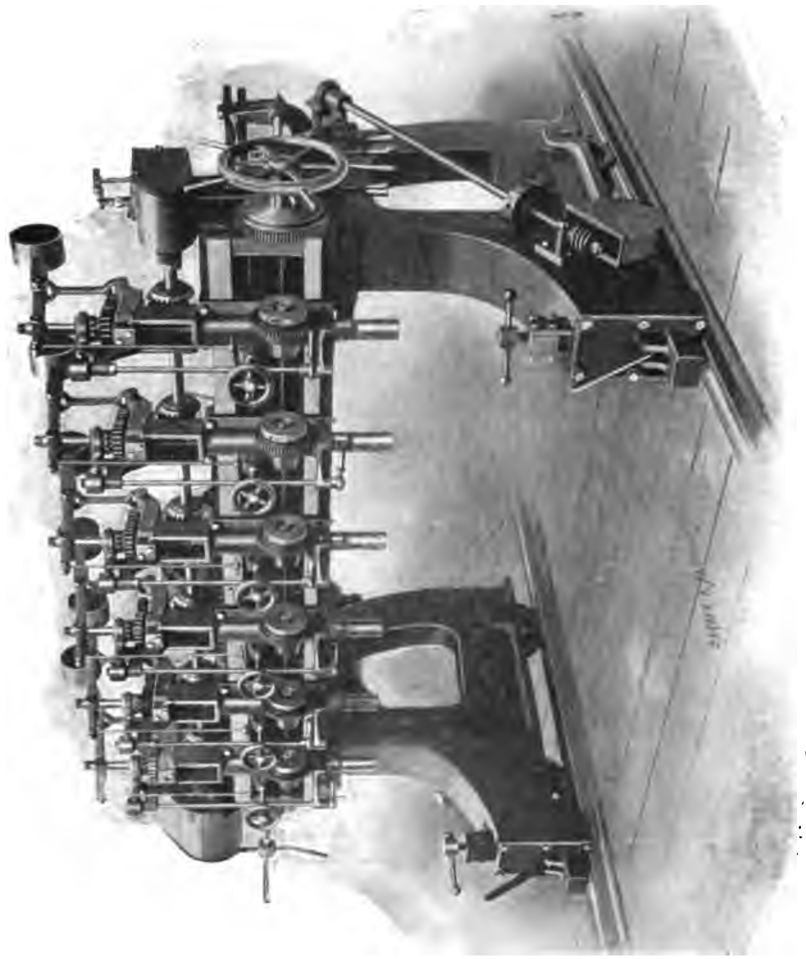


FIG. 72.—Multiple drilling machine.

the fault. The steel was said to cause the drill to run until the snapping point was reached, and so many delays occurred in changing and the expense seemed so heavy that the reactionary movement became very strong. The

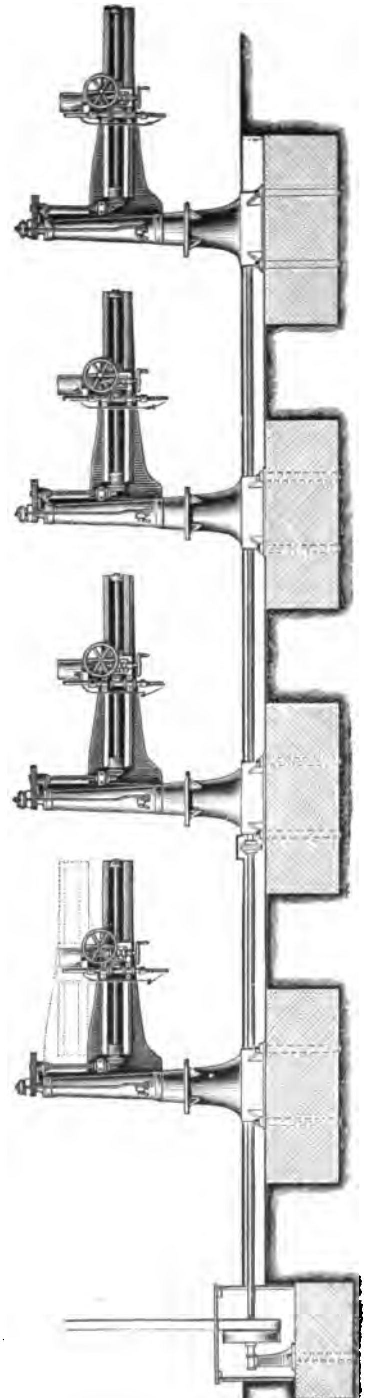


FIG. 73.—Nest of drills for girder work.

binding action of drills running out of the straight was often so powerful as to stall the machine, and the subsequent operation of restarting may be better imagined than described.

Single drills came again into favour, but in the form of radials and in "nests" of from three to half a dozen, similar to fig. 73. That is to say, these numbers were placed in line and driven by common shafting, in such a way that their radius of action overlapped so that they were able to completely cover any given length of flange plate. The theory was that, since the drills were single, less time was lost in changing, besides which there was no cumbersome head or bed to move, a slight swing of the radial or turn of the horizontal screw being sufficient to move from hole to hole. The drills were simply made; only a pillar with swinging arm and fitted with vertical power feed—no delicate movements and mechanism such as the fitting-shop drill is equipped with, nor was any table provided. One man and a boy could look after a nest of six, so that practically the same number of drills could be running at once. It was also claimed that the cantilever arms allowed a little give and take, which, while detracting somewhat from the perfect shape of the holes, contributed towards lessening the drill breakages. Another advantage was quickly realised. Small rail tracks were laid either side the drills, and trolleys made suitable for them; on the trolleys the girder flange was built up and then drilled as it lay. A flange could be assembled on the one set of rails, whilst another was being drilled on the other, and *vice versâ*. This altered methods altogether; as many trolleys could be used as was necessary to keep the plates straight, dispensing with tables, and then simply run under the drills. The saving was plain and the demand for multiples fell off appreciably. By laying a few rails, heavy loads could be moved with comparatively little effort, whilst the trolleys were most handy for light assembling.

Up to now radial drills have undoubtedly remained the favourite means for either reaming or drilling, although much of the prejudice against the multiple has died out. Twist drills are very different to what they used to be, and though drilling through the solid is still a difficulty with multiples, yet reaming can be very quickly and efficiently done. So far as capital cost goes, there is not much to choose between a multiple or a nest of radials, the advantage the latter possesses being that they take up less floor-space and they are credited with needing less power. It is a mistake to pay for any refinements on radials for girder work; they want to be perfectly plain tools with good long bearings and big collars to do the best service. A new tool lately introduced is shown in fig. 74. The work is laid on the bed, which is about 50 ft. long, and the drills are fed backwards and forwards over it. It is really a compromise between the radial and the multiple, and possesses advantages for some types of work.

One of the points in favour of reamed work is that, since there is already a fairly true punched hole which only requires widening out, the drill has no tendency to run, but will follow the hole. Given good templating and nipple-punching, holes will be vertical, and thus a binding action does not get set up.

Naturally less power is consumed, and belts and gear run all the longer and

Fig. 74.—Six-head girder-drilling machine.

sweeter. Another thing is that fewer chips are made, since there is less metal to remove and the burrs are not troublesome. This latter is a point

against drilling from the solid which is not generally appreciated. No matter how well bolted together several plates may be, when a drill is forced through them burrs are set up on every plate. Admittedly a good deal depends on the drill; if badly ground and the cutting bad, big burrs are bound to result; but even when properly attended to drills will set up an appreciable amount of burring when drilling through the solid. If the flange gets riveted up in this state, there will be an infinitesimal distance between each plate, caused by the burrs holding them apart. One of the great advantages of hydraulic riveting is that it exerts a tremendous pressure on the plates and thus draws them tightly together. If, however, there is a burr at each hole, these cannot be entirely removed by compression and are bound to hold the plates slightly apart. This means that the atmosphere has access to each surface; that sooner or later oxidation will set in between the plates; and that through inefficient contact the plates may slightly work under moving loads with disastrous resultant consequences.

It is not improbable that in the near future the new grades of tool steel on the market will be applied to steelwork drilling, and that a strong case will then be made for drilling all holes from the solid. At the present time it is possible to put a hole through 5 or 6 in. of solid mild steel in about a minute, and there seems every inducement to do away altogether with punching small and do the drilling first. Whether the trade is or is not coming to this it is yet far too early to prophesy, but, admittedly, drilling from the solid is the ideal way. If it were possible to plane all plates to length and assemble them on the tool-bed, merely marking the rivet positions on the top plates, and then drill right through the lot, a tremendous saving of time in templating and handling alone would result. We have not yet approached this, but manufacturers will be the first to welcome such a change should it appear feasible, whilst for designers the results would be ideal. The bugbears of running and burring appear to be the greatest drawbacks to its realisation. Drilling through solid metal is very different work to going through several layers, each one of which may differ slightly in homogeneity or density from the others. It may be that the rate at which the work is done will mitigate the trouble, though it rather appears as though it would only serve to accentuate it. Still, it is never safe to predict too much in untried possibilities, and should it happen that the new tool steel is to solve the problem, no one will be better pleased than makers. One great difficulty would be power, and whilst new tools might be bought and laid down, it would in many places be a problem as to where the extra horse-power would come from. A method which is even now being tried in one or two of our leading works is to punch the flange plate next to the angles only, and then when the flange is assembled place it under radials fitted with high-speed drills. The first plate being punched provides against the drills running from their proper position when starting, as they generally do if there are only punch poppet-marks for guides.

If running takes place it is only a question of toughness of the drill and driving power; the mere fact of running will not matter to the work itself.

So long as the hole is true and properly filled with the rivet, it matters nothing whether it is exactly vertical or a little on the angle, so far as the strength or the life of the work goes. It is different with burring; if this takes place and is not removed, the life of the girder is bound to be affected. All plates should be carefully and well painted before assembling (unfortunately they seldom are); but one coat of paint will not last for ever, and if the weather can get at the surfaces they will begin to corrode in time. If the burrs are all to be removed, the flange must be taken to pieces after drilling, and each surface thoroughly gone over, be painted, and then put together again—a very big job. Some of the advantages of drilling are bound to be qualified if this is done, since the plates will never again take the precise position they occupied before.

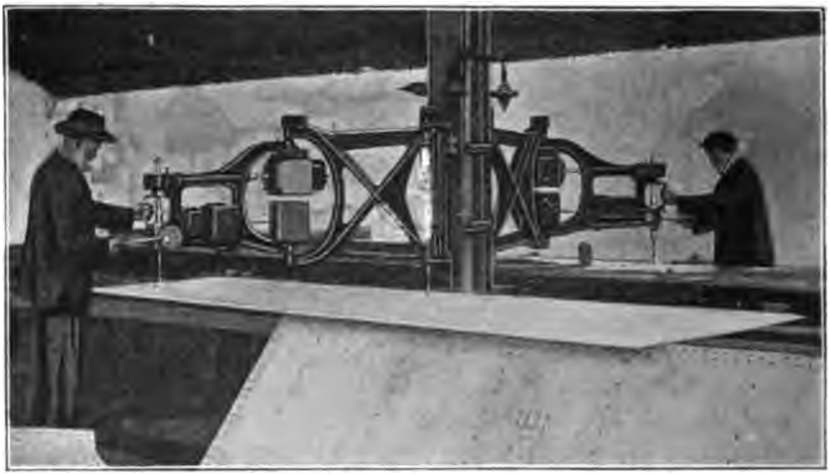


FIG. 75.—Radial drills for light work.

Typical drills for light work are those made by the Oerlickon Company; they are electrically driven, and can be arranged to work the same as radials (actually they are miniature radials). For small holes through light work they are very good and fast working, and, being light and easily handled, they cover a lot of work very expeditiously. Fig. 75 shows them very well, and their handiness will be apparent.

Further drilling operations will now be regulated by the size of the work in hand. If girders are small and within the capacity of the radials or multiples, the flanges and webs can be assembled and service-bolted together, the girder turned on its side, run under the machines, and reamed as it lies on the trucks or bed. If drilling from the solid is being done, a few tacking holes through the angles and webs for the reception of the bolts will have to be drilled by hand. Should the complete girder be too large for the drills,

there is no help for it but reaming in position, although, if of Warren or Linville type with heavy members, these can generally be taken to the machines for all but the holes jointing them to the booms. The aim will always be to get as much done at the drills as can be schemed, since handwork—no matter how good the apparatus—is sure to be the most expensive. On large plate girders, for instance, the gussets with their angles or tees will be machine-drilled, leaving the holes into webs only for handwork; in large and heavy booms the only holes left will be connecting ones, and so on.

Assembling will usually take place away from the machine tools, so that there may be a clear space unhampered by shafting and belts or material awaiting machining. If large work is being put together, there must be both good head-room and large floor-space free of any obstructions, and with a thoroughly efficient crane service. When holes have been punched small they will be a very great aid in putting together, since a ready means is to hand for temporarily securing the parts together. Let the engineer imagine how he would begin to assemble a long-span railway bridge of open-web formation—say 200-ft. span—when his booms are each in eight or ten lengths with blank ends, and his diagonals and braces also with blank ends, and there is an inspector on the job to see that every hole is undoubtedly drilled through the solid in position! Pieces of all sizes and weights up to, perhaps, 4 and 5 tons each have somehow to be steadied and held in position whilst holes are being put in! Few shops would willingly undertake such a job in this country; the American would laugh at the idea. Of course it can be done; brains and tackle can do almost anything, but such requirements are absurd and childish in the extreme. When punching small and reaming out to size is capable of giving just as good a finished job at a tithe of the trouble, the practical man may be forgiven for thinking hard things of the theoretical man's ways. The expense attendant on shoring into position, erecting false works, the poles and derricks necessary, with steam or electric cranes idle for hours merely supporting a ton or two whilst holes are being put in, is enough to try any works manager's temper severely. Generally, such jobs are specified to be erected before delivery, although perhaps it would not be wise to attempt to do such work *in situ*; yet the presence of erecting tackle in the girder shops always seems out of place and a thing to be avoided. There is, however, no royal road to the solution of the problem. If it has to be done, risks must not be run through deficient tackle; and if the size of the job renders it necessary, temporary scaffolding must be built and the work put together as accurately as possible, drilling proceeding as quickly as may be and always keeping pace with the assembling. It will, however, be plain that with no holes to help in drawing tight and forcing joints close, it is difficult to get as good a job with blank ends; the small punched holes may be used for drifting tightly into position, and the whole girder can be temporarily put together and its truth verified before getting too far with the reaming and riveting.

For reaming in position the ordinary ratchet brace is still much used,

but pneumatic or electric drills are more in favour. Where a compressed-air supply is available the first-named are as yet unsurpassed; the little tools are light and portable, and may be carried anywhere on scaffolding. In appearance they are very similar to fig. 34, only larger and heavier and fitted, of course, with the proper drills. Naturally they work far faster than hand methods, and get through a surprising quantity of holes in a very short time. They are used in cradles exactly as for hand-ratchet braces, and can be fixed to work in any position. Electric drills are not yet very largely used, though indications are that they will grow in favour. Unless the general plant is electrically driven, there is a difficulty in supplying these small hand-tools with power, though a portable apparatus is now on the market; it thus happens that the compressed-air methods have at present a big pull over the electric ones, and we hear much more of the former than of the latter. Perhaps prejudice may also have something to do with it; the average workman would rather use air than electricity, and he can make air give much the better showing if he wishes. So far as economy goes, it is easy to produce figures proving anything; actually the cheaper system will be determined by the prime movers at work. If electricity is not used otherwise in the shops, it can hardly be expected to prove exceptionally economical for such small tools—the smaller the motor the greater the expense per unit of power used. There will, doubtless, be great strides made in electric driving in the near future, but at present pneumatic plant seems on the whole more suitable and economical, notwithstanding its admitted losses by friction and leakage.

With reaming only to be done in position, assembling is not a very big job, and holes are quickly ready for their rivets. It is not skilled work to enlarge a hole, though it becomes so if any marking out or drilling has to be done. The saving effected by reamed work is not confined to the drilling machine, but is felt right through all the processes. In very many cases it would be the best plan to defer the reaming until erection on site; the small punched holes will serve for the temporary yard erection, and these would be readily enlarged on site, when the vaunted superiority of perfectly true holes would be taken the utmost advantage of. It would not be practicable in all cases, but if joints are driven up tightly, as they should be, and the holes drilled or reamed to size, and then the joint is broken to be put together again subsequently, it must be patent that the precise former position will not again be obtained, nor a very near approach to it, unless a lot of drifting and objectionable forcing into place is resorted to. If reaming or drilling in position is worth anything at all, it is worth much more if it takes place at the final stage. This is by the way.

The assembling of steelwork will occasionally be more costly than the getting ready of the pieces. If a lot of scaffolding or false work is required, and the work is of such a nature that it has been deemed the safest to do a certain amount of fitting in place, as in a very awkward roof, the cost will run high, because highly paid labour must be employed. With plain bridgework

the travelling cranes and slung scaffolding will usually be all that is necessary; but before large domes and arched roofs and such work can be assembled many props and much scaffolding are sometimes requisite. Whenever possible, the cheapest way is to put up a pole in the centre or convenient position, and use this to build up the work around it. Perhaps no other contrivance is so largely used in outside erection as the single pole; it is just as handy for inside work.

In most girders there will be camber, and, even if the drawings do not ask for any, a little will be put in, since all work—large or small—settles a trifle when it gets on its bearings. Nothing less could be expected from the multitude of holes and rivets and small parts of which any structure must perforce be built. In plate girders it must be allowed for in the webs, and when ordering material this must not be forgotten. If a girder 40 ft. long is to have 1 in. camber when finished, the girder yard will probably reckon on 1½ in. or a little more. If the web plates are properly shaped, the flanges will follow suit, but enough material must be allowed. Supposing that the web is in two parts, that is, one joint in the centre, and it is 4 ft. deep, the ordinary rule would be to order the plates 4 ft. 0¼ in. wide, but since this would not cut the camber, they would have to be at least 4 ft. 1 in. They would then be set up a trifle at the centre, and the extra width would provide what else was necessary. In building up girders, especially open-web ones, the timber blocks on which the bottom flange is laid should be graduated to suit the desired camber, and the mere weight of the structure will cause it to follow the correct lines. When riveted up and put on its bearings, it will sag down a little with its own weight (for which the extra girder-shop camber allowance is the provision), and the finished camber is supposed to be such that, when the full load to be carried is assumed, the girder will be practically straight.

It should be mentioned again, as a point to which too little attention is usually given, that plates ought not to be laid against each other and fastened together without being given a protective coating. Very often the only covering steel has is that which can be seen when finished, and more trouble is likely to arise from this reason than from any other. Wherever a surface is covered up, as in overlying flange plates, angles to webs, cover plates, etc., the covered surface should either be painted or oiled—the latter for preference. Good boiled oil put on before riveting will not be messy like paint; it does not contain any adulterations, and it will prove of immense benefit in resisting corrosion. If, as suggested in an earlier chapter, coating all material before it left the mills was adopted, there would be no need to do it just before riveting; but, failing that, it should never be omitted.

Countersinking of holes has not yet been specifically mentioned. It will seldom pay to do this on the machine, such holes being so few and far between. They are, consequently, generally put in by hand afterwards, unless (as sometimes happens) a whole flange has to be countersunk, and then the case is different. It is not hard work to countersink a few odd holes, and a labourer will soon do what is required with the ordinary ratchet brace or pneumatic drill.

CHAPTER XVII.

THE GIRDER SHOP—IV.

RIVETING, which follows assembling, is quite the most important operation in girder-making. Whatever may be said as to the merits or demerits of punched or drilled holes, planing or no planing, wood templating and nipple-punching, opinion will be general that it is in riveting that the greatest practical responsibility lies. It is in the soundness and strength of the thousands of little clenched pins we term rivets that the safety of the structure will lie, just as much as it does in the draughtsman's calculations. Let a few of them in an important joint be burned or otherwise injured and collapse may very well ensue.

There are many considerations affecting good riveting; in a former chapter we reviewed the influence heating plays on its soundness, and drew certain conclusions therefrom. It will be as well if we now discuss the remaining essentials.

First and foremost, the rivets themselves must be clean and good, with perfectly formed heads, no frazes, and with clean necks. As most people know, they are made from the bar in special machines, which cut them off, head, and clean them; and in order to be good themselves, they must have been well heated and pressed in clean dies. If anything, the points must be smaller than the shank, but it is important that the shank is not taper in either direction, but that it holds full and true throughout. There must not be any fillet in the neck, as in fig. 76; but they must be clean, so that a single stroke will drive the heads up to the work. If there is any rounding the heads cannot come up to their places properly, and bad riveting must follow. No cracked or deficient heads should be allowed; they should be so sound as to allow of flattening out cold with the sledge, without showing signs of imperfect welding.

They ought to be heated according to the method of driving to be used, as already determined, with the object of obtaining the soundest job in all cases. In connection with this it should be stated that experiments have proved that the greater the load used for driving, the stronger the joint. Within the capacity of the rivet this is bound to be the case, since the more pressure used, the closer will the plates be brought together and the

greater the frictional contact. Again, the closer the plates, the less chance of a bending action being brought upon the rivet, and the nearer its strength will approach to its full shearing value. If rivets could be put in cold and given a perfectly formed head under a tremendous pressure, the condition would be ideal. They would not contract further, whilst they would hold the plates in the contact the dies pressed them to. Since the points must be heated for machine work, a certain amount of contraction will always take place; and so long as this is not sufficient to injuriously affect the rivet no harm will be done, but the job made all the better. Consequently, high pressures are to be esteemed in riveting so long as the proper heating can be obtained. As close a contact as possible between the riveted surfaces, a rivet with perfect heads, and an unstrained shank properly filling the hole—these are the essentials to good riveting.

To secure them all is not by any means a simple matter. If a big pressure

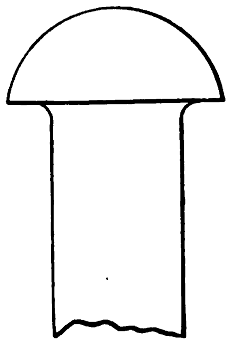


FIG. 76.—Rivet with fillet.

is put on the plates, the rivet is apt to be strained through cooling. If perfect heads are secured, they may fly in contracting; if an unstrained shank is obtained, the plate contact may be bad. It will not be the tools employed which will rule whether the riveting be good or bad—each system has its own characteristics and advantages—but the general management of the process. That thoroughly good work can be secured by hand-riveting is a proved fact; that execrable work can be turned out by hydraulic or pneumatic machines can be seen every day. The rivet must be suited to the tool, and the tool to the work; but, above all, the men must be masters of their job.

With hand-riveting most engineers will be perfectly familiar. A gang will consist of three men and a boy—one holder-up, two riveters, and the boy to heat the rivets; sometimes a second boy is needed to pick up if the fire is far from the riveting spot. In riveting a flange the rivet is pushed into the hole from below with a small pair of tongs, and the holding-up hammer placed on its head. This tool is a hammer-head with a recess in

each face to fit a rivet-head, and it has a strong wooden shaft of some 5 to 7 ft. in length. The shaft is placed about a foot from the head, in a sling conveniently hung, and which acts as a fulcrum; pressure on the end of the shaft then forces the rivet up to its place and holds it there during the process of riveting. The hot point is well hammered down by the two riveters with hammers having long, slightly curved heads; and when well turned over these are laid aside, one man picking up the snap, which is held by means of a hazel stick twisted round it in the same way that a set is held, and the other the flogging hammer, which he wields until the snap has properly rounded and formed the head. Thus the success of the riveting depends on the holder-up offering a good resistance to the two riveters and the rivet being a good white-hot heat, otherwise the head cannot be properly formed, and the plates will not be brought together sufficiently by its contraction. For riveting in confined situations where the ordinary holding-up hammer cannot be used, a short "dolly" is employed, this being a stiff piece of metal about 2 in. or 2¼ in. diameter, and 18 in. to 24 in. long, cupped at the end to receive the rivet-head. It is merely held against the rivet by the holder-up, and wants careful use to get good work. A good hot shank with a point at welding heat is what is wanted for hand-riveting, but this is useless without a sharp, quick gang. Practically, hand-riveting is now confined to those places where a power riveter cannot be used, and for field—*i.e.*, erection—work.

Of power riveters there are three principal types—steam, hydraulic, and pneumatic. The first-named is the oldest, and originally consisted of a piston actuating the dies direct. These were superseded by crank or cam movement actuated by belt or direct by steam, with a fly-wheel, which pushed the riveting snap towards a fixed dolly or hob. Different lengths of rivets were managed by different length snaps. Of course the machines were fixed and all work had to be brought to them; generally a light gantry was built over with blocks on movable carriages, from which the girders were slung. The rivets were heated in a small furnace and put in the work three or four at a time. It was a great advance in economy over the hand method, and for medium-class work seemed to answer fairly well, so long as the snaps were the right length. It was not good work, since there was apt to be very little pressure put on the plates and the rivets were a dull-red heat throughout; heads were neither good nor clean. This system has been developed into MacColl's patent riveter, which is a combination of this method and hydraulics, and which is capable of doing first-class work. Fig. 77 shows the machine partly in section to illustrate the working. Briefly, the cylinder and reservoir are filled with liquid (glycerine and water), which, when the back piston is pushed forward by the mechanism, becomes compressed and actuates the piston attached to the snap; a loaded safety valve is placed into connection with the cylinder, so that, when the pressure reaches a predetermined point, the liquid escapes back into the reservoir. Thus the exact pressure on the rivet is always known, and it is not necessary to change the snaps, as the

machine thus automatically adjusts itself to any thickness of plates and always at the required pressure. The idea is simple, and the tool is not liable to get out of order, and the pressures can be regulated according to the size of rivet being put in. The arrangement is typical of what should be embodied in this class of machines, and will work at pressures up to 60 tons on the rivets, so that it is suitable for heavy work. In action it is very similar

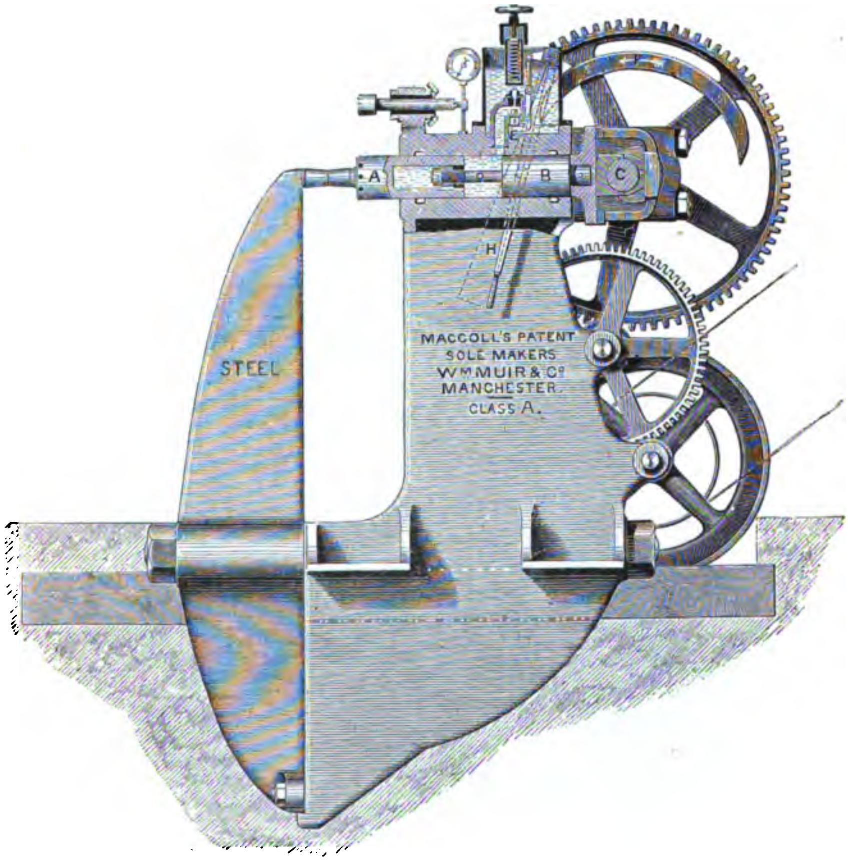


FIG. 77. —MacColl's patent riveter.

to hydraulic or pressure pneumatic tools, and should therefore be fed with similarly heated rivets. The cut shows it as belt-driven.

Hydraulic tools are made in very wide ranges and patterns, though the principle of them all is the same. Pumps are used to force water into an accumulator under varying pressures (1500 lbs. to the square inch is a very usual one), the size of which is regulated by the number of riveters to be fed. This is placed in a convenient central position and acts as a reservoir from

which the tools draw their power, automatic connection with the pumps being made so that the accumulator may never get empty. All mechanism is exceedingly simple in design; the pumps are usually belt-driven, though they

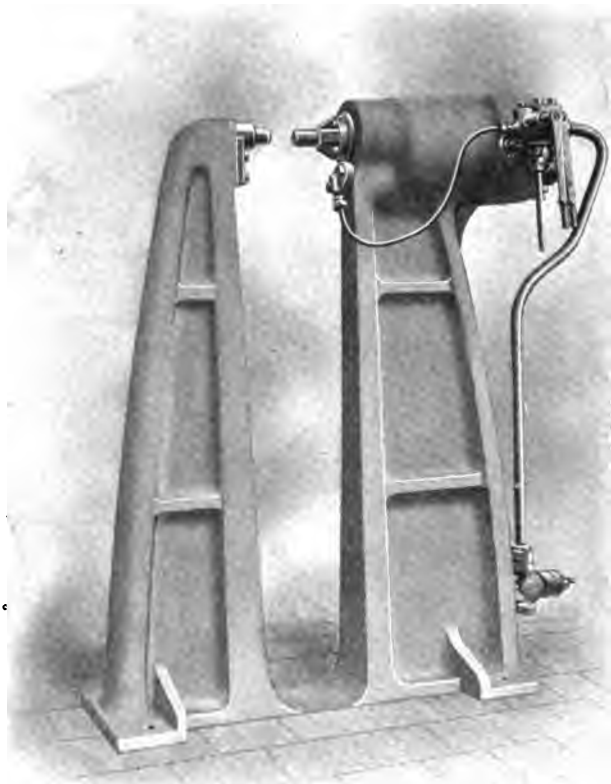


FIG. 78.—Fixed hydraulic riveter.

may be direct steam-acting, and are merely rams forcing the water in front of them; the accumulator is usually a vertical hollow column in which slides a ram which is heavily weighted. The pumps force the water into the column, which gradually causes the ram to rise until it protrudes the full length of its stroke. The water then in the column is at the pressure determined by the

weighted ram. Pipes laid in the ground convey the power to convenient points where it may be utilised.

The machines are of two types—fixed and portable. In the one the work must be brought to the tool; in the other the tool is taken to the work. Figs. 78 and 79 will fairly represent the fixed type, and it will be noted how different in appearance they are to fig 77. The riveting apparatus is merely a cylinder to which the compressed water is led, and this acts on a piston or ram to which

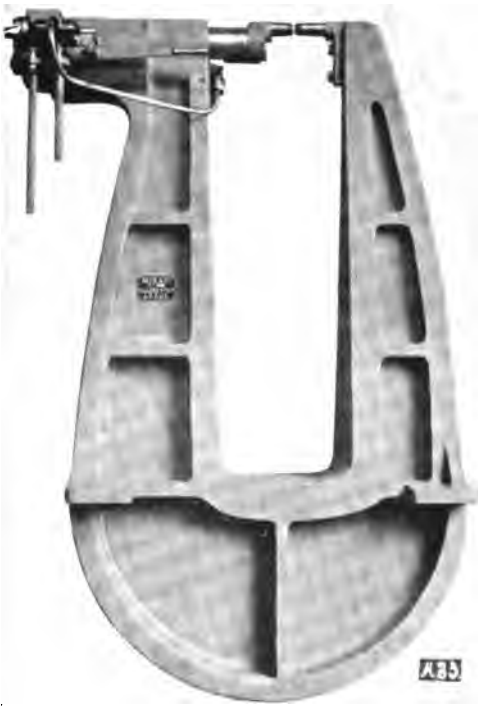


FIG. 79.—Fixed hydraulic riveter.

a riveting snap is affixed, pushing it forward against a fixed hob or dolly. The snap is made to retract by power, and the used water is led back again in pipes to the rams to be used over again, or is discharged, as convenient. Various refinements have been introduced, and efficient controlling valves are necessary, but this is briefly the principle upon which they work. According to the size of the riveting ram and the pressure of the water will the power on the rivet be varied, and tools are to be bought of as low a power as 15 tons or as high as 80 tons.

The highest powers are needed for big boiler or other work where large rivets have to be driven and joints made secure against heavy pressures. The

majority of constructional steelwork jobs seldom require more than 1-in. or $1\frac{1}{8}$-in. rivets, $1\frac{1}{4}$-in. being used very rarely, so that tremendous powers are not so imperative as for boiler-making. At the same time, big girders are not so readily handled as boiler shells, and experience has proved that in nineteen cases out of twenty it is better to take the tool to the work than the work to the tool. Thus fixed riveters are not in much favour in our shops; a small portable one can be carried almost anywhere, and can be handled easily in any position, whilst this cannot be said of big girders.

Consequently, the demand has led to the development of riveters which can be slung from cranes or gantries, and which derive their power from the

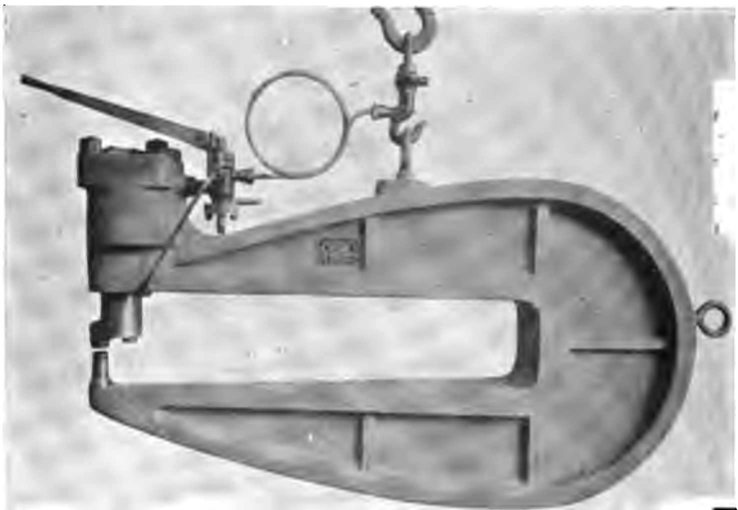


FIG. 80.—" Bear " type of hydraulic riveter.

pressure mains, connection thereto being by means of flexible or jointed copper pipes. They are made in two types—the "bear" type, with cylinder over the snap; and the hinged type, with cylinder as far removed as possible from the snap, and are respectively shown in figs. 80 and 81. Fig 81 is a special design for girder work, and whilst some shops seem to use them exclusively, others which have both generally use fig. 80 in preference. The hinged type is supposed to be preferable to the bear type, because the snaps are clear of the cylinder and valve, and are therefore capable of being poked into more confined and awkward positions. Undoubtedly this is so; on the other hand, there is an important joint extra, whilst the cylinder and ram do not work truly vertical (neither do the snaps), and more difficulty is experienced in guiding and handling. A hinged riveter always seems to leak more and need more attention and repair than a bear one, and so shops get in the habit of

using the latter—perhaps because they are more often available for use, and putting in those rivets which cannot be got at, by hand. On most girder work the riveting is plain and straightforward, and the "bear" will do as much as the hinge. For general work two or three of the "bear" type and one of the hinged seems the best policy—especially as the latter is a trifle more costly.

A simple riveter is the best—as plain and inexpensive as can be bought. The elaborate hanger shown in fig. 81 can be fitted to either type, but it is only in the way on straightforward work. One would be useful at times, but no more need be purchased—it would only be waste of good money. Labourers can be trusted with a perfectly simple machine, and they do work

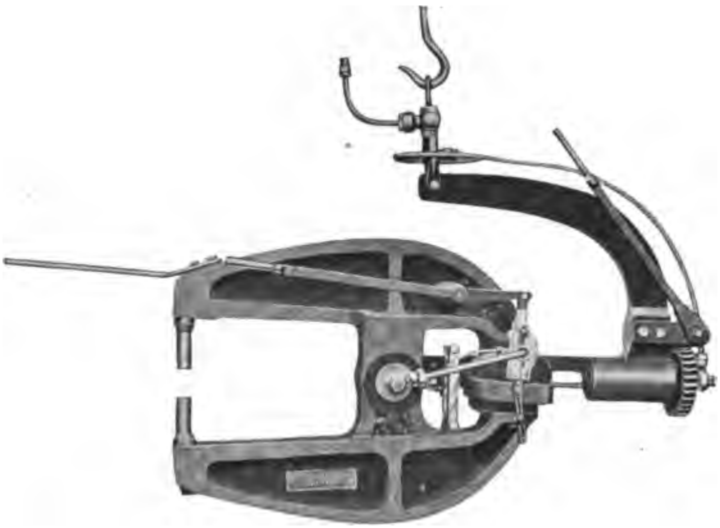


FIG. 81.—Hinged hydraulic riveter.

just as fast and well as skilled men; but if complications are introduced the labourer is quickly at sea and requires too much oversight to make his employment pay. Two youths and a boy will be well able to work one riveter, and on straightforward work will put in about one hundred rivets per hour, at a labour cost of about tenpence. The saving over handwork is apparent, when one hundred rivets may cost seven and sixpence. Hydraulic riveters have been worked at the rate of nearly two hundred rivets per hour, but this is exceptional.

Some of the larger riveters are fitted with "plate closers," which are simply auxiliary rams operating so as to squeeze the plates together before the rivet is snapped. They are useful when thicknesses are heavy and bolts do not draw plates closely together; but they are a little superfluous in the girder yard, where layers generally lie fairly closely and service bolts are

sufficient for all ordinary purposes. They only add complications for not much gain, and their proper sphere is boiler-making.

Practically the only difficulties found with hydraulic machines are keeping the packing tight and preventing loss of water through leakages in pipes and their joints. U-leathers are usually considered the best for all rams, whilst frequent attention is the only thing to keep pipes and connections in order. One point in favour of hydraulics is that power never goes long to waste without attracting attention. The men at work will not get wet through without speaking about it, and a leaking pipe is always plainly to be seen. Some makers prefer to conduct the water to the tool by means of jointed and bent copper pipes from the main, averring that flexible hose is unreliable. Some makes sold undoubtedly are, but hose is to be obtained perfectly well able to stand up to 1500 lbs. per square inch, and there is no question as to which is the handiest in use. Copper pipes have to be most carefully used or they are an incessant nuisance, the springing in the lengths always tending to play havoc with connections. It pays over and over again to get good wired flexible hose and renew it as it wears out; it can be carried and looped anywhere, and is not a tithe of the trouble in disposing of conveniently as is a copper pipe. If flexible metallic hose could be made to carry the pressure, there is no doubt it would possess great advantages over either. There are several different patterns of unions and turn-on valves in the market, any of which from a good maker may be relied upon.

As regards advisable working pressures on the rivets there are many opinions, as is evidenced by the great range of powers it is possible to buy. The primary object being to snap a thoroughly sound head and to squeeze plates closely together, it follows that if the rivet iron or steel was good enough a very low heat with a very high pressure would be at least as good as a high heat with a comparatively low pressure. A very high pressure and heat combined are not desirable, for reasons stated in Chapter X. A high pressure is not really necessary to make a good head unless the heat is low, so that for best results pressures should be graduated to heats and diameters. This is not feasible; if complications are introduced other advantages are lost. Riveters are to be bought which are capable of exerting double power when required, or nearly so; that is, if 25 tons is their normal pressure, they can be so fitted that it can be increased to 45 tons; but they are only recommended for abnormal occasions—the ordinary riveter which has to take the brunt of the work ought to be as plain as it can be made. A simple way of varying pressures would be to alter the accumulator loading, or the employment of intensifiers; but this would mean altering all the riveters at work, which could not be allowed, besides meaning that all pipe-lines, hoses, and riveters, etc., should be capable of carrying a high pressure per unit of area.

Rivets may only be heated in a way which will pay and is feasible. We shall have occasion to deal with the various methods available presently; in the meantime it may be stated that average accepted pressures are 20 tons for a

$\frac{3}{4}$-in. rivet, 25 tons for a $\frac{7}{8}$-in., and 30 tons for a 1-in., and these will be found ample for ordinary work. They are sufficient to ensure good heads at a moderate heat, and are not too much if occasional rivets should be hotter than the ordinary. There is another factor which enters to an extent into the matter and which has not yet been mentioned—the question of the number of thicknesses coming together. It is sufficiently obvious that two $\frac{1}{2}$-in. plates riveted together will not need the pressure which eight $\frac{1}{2}$-in. plates do to make an equally good job, and it follows that the heavier the work the greater the pressure required also. Fortunately, heavy work and heavy rivets generally go together, and the pressures given will be suitable for all-round use. If $1\frac{1}{8}$-in. rivets are to be used, about 35 to 40 tons might be used, and for $1\frac{1}{4}$-in. up to 50 tons. At the same time, if the riveters available are not capable of this power, the rivets may be made hotter than usual and put in at the lower powers, when practically the same results will be obtained. A medium-sized shop should then be equipped with tools of different powers; if it is possible to have five or six in the plant, it will be of advantage to have them of 20, 25, 30, 40, and 50 tons capacity, and they can then be used to the best advantage. If the plant is small, riveters of 25 and 35 ton capacities will be the handiest, whilst if only one tool is required it is hardly likely that big work will have to be tackled, and a low power will then be suitable.

It must not be overlooked that very differently sized gaps are required at times according to the work being done, and the tools must be bought suitable for this also. The most convenient sizes seem to be 12-in., 18-in., 24-in., and 30-in. gaps, with perhaps a 36-in. one as an extra; their widths are also important, and corresponding figures would be 9-in., 15-in., 18-in., and 20-in. The 12-in. × 9-in. makes a very handy size for running down flanges, and if a 12-in. × 24-in. can also be afforded it will be of great help in closing the rivets through angles and webs. The 30-in. × 20-in. will take most of the web rivets in medium-sized plate girders. Small, easily handled riveters are much preferred by the men to large clumsy ones, which only justify their size once in a while. It is far cheaper to go quickly over ground leaving out a few to be put in subsequently by hand, than it is to go slowly over it because the tool is unwieldy, although every rivet may be put in. Stationary riveters may be left alone without any great loss for girder work.

Pneumatic riveters are of three types—toggle-jointed, pressure, and percussive; and as they are later comers than the hydraulic system, they have not yet had that thorough winnowing which the latter has gone through. Figs. 82, 83, and 84 illustrate each type, and it will be seen how much they vary externally. The first two are pressure tools, the one communicating through a toggle joint, whilst the other is direct. Naturally there will be somewhat less wear and tear on the direct than on the toggles, and in so far the one is better than the other. As a set-off the direct type has a large and unwieldy cylinder which is somewhat in the way, and the gap and frame are

not what one has been accustomed to in girder riveting. On the whole, the toggle riveters seem to hold the field at present, and they have done and are doing some very fine work. Compressed air possesses advantages over water which cannot be denied; perhaps its best recommendation is that no freezing

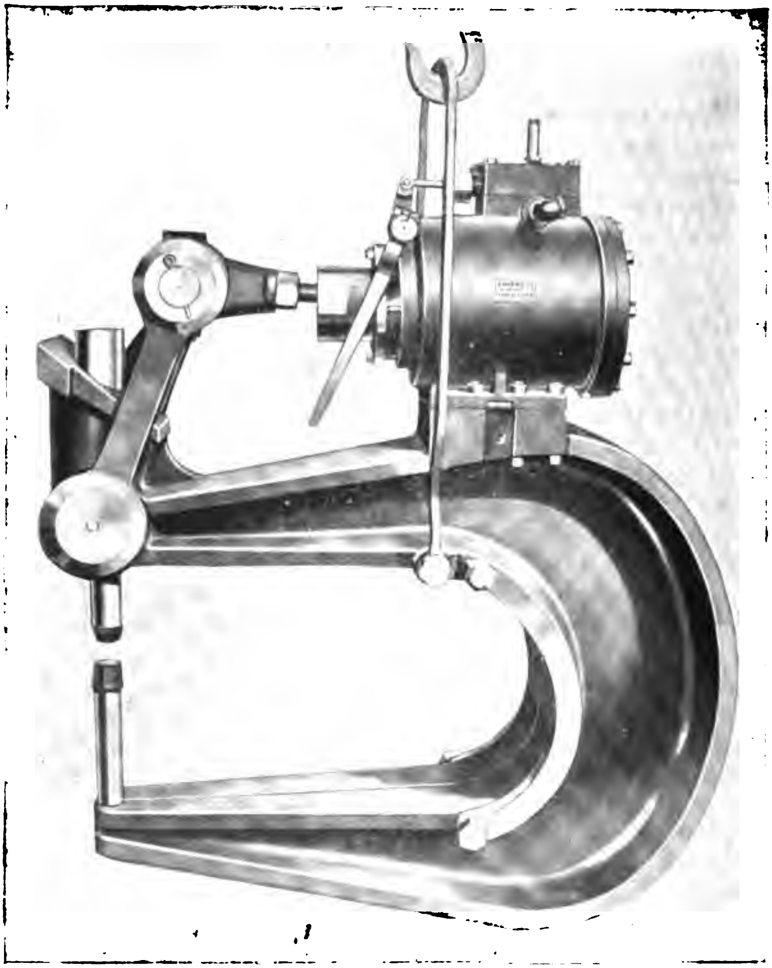


FIG. 82.—Toggle-jointed pneumatic riveter.

of pipes is to be feared in winter; and secondly, the lower pressure worked at permits of much less expensive mains and connections being put in; no return system is wanted either, and these three points must weigh when the instalment of plant is being considered. Hose and piping to stand 80 to 100 lbs. pressure is much more readily purchasable than if 1500 lbs. has to be carried. The compressor necessary will correspond to the pumps and

the receiver to the accumulator; pipe lines and hose are equally required, so that there is great similarity in the two systems. As regards first cost, perhaps the pneumatic has the advantage; and if water happens to be dear, there may be a little saving in this respect in the upkeep. Again, the pneumatic system is convenient for the smaller hand-tools—drills, chippers, and riveters. The first two have already been dealt with, and the third is an

FIG. 83.—Direct-pressure pneumatic riveter.

application of the same principles. The hand-riveter is simply an enlarged chipper, and there is no doubt but that it is in good hands a most efficient tool. Fig. 85 illustrates it, and it can be obtained in various sizes, designs, and weights to suit different diameters of rivets. It is used in conjunction with either the ordinary holding-up hammer or dolly, as for hand-riveting, or with a pneumatic holder-up, as fig. 86. The last makes the best job where it can be used, as it provides a solid resistance to the hammer strokes; but as it needs a support or rest of some nature, it is not applicable to all circumstances. Practically it consists of a cylinder into which air is admitted,

thus forcing a piston outwardly until it meets something stable, when the air-pressure inside keeps it in its place; a flange or bar resting on an opposite side or flange will serve the purpose. It is claimed that these riveters will drive rivets up to $1\frac{1}{2}$-in. diameter, but they are exceedingly tiring on heavy work, though perhaps not more so than any other hand appliance would be; still, rivets of that size are really beyond anything but the heaviest machines, unless they are in positions where they cannot be otherwise got at, when the best obtainable job must perforce be made. For ordinary shop and erecting work up to 1-in. and $1\frac{1}{8}$-in. rivets these hammers are exceedingly useful, and

FIG. 84.—Percussive pneumatic riveter.

will do a lot of work. They are quite simple in construction, being nothing more than a rapidly moving piston actuated by the compressed air, which strikes the snap several hundred times per minute. The force of the blow is not equal to that made by a riveter with his hand-hammer, but since there will be ten or twelve blows given to every one of the latter, better work—or at least as good—can be done, whilst it will be much quicker.

The percussive portable riveter is really a hammer inserted in a gap frame, as will be seen from fig. 84. It possesses the advantage of being its own holder-up, and it is naturally much lighter than either the toggle or pressure types. For places doing light work with only a minor amount of riveting it is well adapted, but it can hardly be classed as equal

to the other types for everyday use. It is not suitable for heavy structural riveting.

The special point of recommendation in pneumatic plant is the great variety of uses to which it can be put. Riveters of the stationary-pressure kind may be had which will exert a pressure of 75 tons and more, or they may be had in any intermediate power, both fixed and portable, down to the small percussive hammer just noticed—all this at the same receiver pressure,

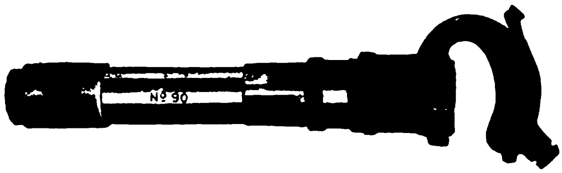


FIG. 85.—Pneumatic riveting hammer.

and all fed by the one receiver if desired. It is evident that to many shops such a range will appeal strongly, and there is small wonder that the system is being so widely taken up. Where extensive chipping, caulking, field drilling, reaming, and riveting has to be done compared with a moderate amount of shop work, it cannot but be admitted that pneumatics are first

FIG. 86.—Pneumatic holder-up.

favourites. Nearly all small concerns, and more extensive ones dealing with light work, will be suited by this plant. It cannot be said that it is as successful with heavy as with light work, or that it is as well adapted; but its versatility is at present unmatched by any other agent.

One point must be emphasised, and that is, that for all percussive riveting the rivets must be hot throughout with white-hot points. There is no plate-closing effort exerted beyond the hammering given, and contraction is needed to draw the plates together—more especially so as layers increase in number. A white-hot point is the essential to a good head, and a hot shank to prevent loose rivets and slack plates.

In comparing pneumatics with hydraulics, it is necessary to clearly have before us the aim in view. Both systems are simple and free from complications, and when there are two such strong rival claimants to favour all prejudice must be laid aside and the matter considered solely from the point of the end to be accomplished. From what has been said the reader will have gathered that all the advantages are not on one side only. Owing to the immense initial pressure, trying on mains and connection pipes and valve, but rendering the tool simplicity itself, hydraulics have undoubted claims to heavy work. So long as leakages are not present, less skilled men can be trusted with the tools, whilst breakages are practically unknown. In order to get big loads with pneumatics, either a multiplying toggle device must be used with its extra joints and machinery, or big cylinders with their cumbrousness employed. Both are capable of making good results, and where only a little heavy work is needed they will serve, but where there are joints there are repairs, and there is extra weight and size to be moved and handled in both.

Looking at the practice of our foremost works (and it would be odd if the practical men in charge were very far wrong), and employing the results of our reasoning, we see that hydraulics are very far from being ousted by their younger rival. For heavy continuous service they are still, and rightly so, preferred. Where the proportion of shop work exceeds that of field or assembling work, as it does in most large shops and many medium-sized ones, they are the best tools for the purpose. Well-made apparatus and services give very little real trouble if looked after at all, whilst the portable tools are handier and more easily managed. Both fixed and portable tools have a longer life and need less repairs than do pneumatic for heavy continuous service. The higher we go in the scale of loads, the more advantage is shown by hydraulics. Tools giving up to 200-tons riveting load are to be found in some works—an almost impossible amount for pneumatics.

Where, then, the plant is large, and also in any place having runs of straightforward riveting, a combination of hydraulic and pneumatic tools is usually found, the latter being in use for field and assembling work. One or two portable pressure riveters for putting in rivets through several thicknesses, a few percussive hammer ones, with chippers and drillers, will be equal to the assembling demands of a large establishment, and for this they cannot be beaten.

Again, where shop work is light, as in places making a speciality of roofs and light work, and where there is not much straightforward riveting, but much of it must be done in place, or a little at a time, a complete pneumatic plant will be the favourite. In such a shop one pressure riveter will seem to do a lot of work, whilst the percussive ones—one or two with a gap attached—will be always in demand. It will not be worth while running two systems, since all that is wanted can be had from the one.

Rivet-heating apparatus—perhaps the most generally neglected process in all works—must now be briefly noticed. During the discussion on tools

and rivets desirable conditions of heat have been stated, and it may at once be said that there is no really efficient means of properly and uniformly heating rivets yet on the market. There are gas fires and muffles, oil furnaces, and coke fires of seemingly endless description, every one of which is urged as the solution of the problem.

If rivets at a uniform red-hot or even white-hot temperature are the end and aim of all apparatus, then there are several which may claim to be efficient, and figs. 87, 88, and 89 will show their construction. They are typical of the best yet to be had, and will undoubtedly do as their makers claim—

FIG. 87.—Portable rivet furnace.

turn rivets out at a regular heat without burning. It is this latter bugbear which has obscured the real question. Burnt rivets are and always have been dreaded by both maker and engineer for evident reasons, and apparatus has been sought which would effectually get rid of a very serious trouble. On all hands it is admitted that they cannot be tolerated, and so far very good service has been rendered. But as the burnt rivet has practically made its exit, in has come the cracked head and heads which fly on cooling. With the old-style hand-riveting, cracked heads were comparatively unknown, and were always recognised as being due to too low a heat; nowadays they are put down to inferior material. Metal is now so ductile that a head can almost be hammered cold without seriously splitting, and so a defect really due to

deficient heating has been largely met by a better grade of steel. So far so good; there does not seem any valid objection to this. But heads which fly want a different explanation, since they indicate that something is wrong with the shank, and it is this which is being ignored by those who should know better. *A red-hot shank is not suitable where great pressure is employed.* Reason and common sense both argue that when plates are as close as they

FIG. 88.—Rivet furnace.

will go, stress must be set up within a contracting rivet—a stress it should not be called upon to bear. The mission of a rivet is to hold the plates in the position the power dies have left them, and to be able to exert its full strength when called upon. If it were not for our large factors of safety there are many structures which would to-day be absolutely unsafe. It is not too much to say that many rivets are subject to stresses which the designer never contemplated and has not the faintest notion of.

A red-hot shank is a necessity when contraction is relied upon to bring surfaces in proper contact, as in hand and percussive pneumatic riveting.

It is here of distinct service, and so long as the point is hot enough to be properly snapped by the tools nothing more need be asked. A uniformly heated rivet is particularly suited then to this riveting, and will do better work than any other.

But for high pressures a cool shank and hot point are necessities. There must be as little contraction as possible, whilst there must be sufficient local heat to ensure a good head. The days of punched work are now apparently so nearly over that the obligation of upsetting the shank does not now exist.

FIG. 89.—Portable rivet furnace (another type).

Rivets fit their holes tightly, and do not want to be any warmer than conduction allows, and the problem of providing this has yet to be solved. The longer the rivet the greater the necessity, since the more contraction there will be.

The old way of a coke breeze fire and the rivets suspended through holes punched in a plate is something of what is wanted. The shanks should be protected and the points exposed to the heat. This sounds simple and easily secured, but the difficulty is to keep up a sufficient supply. One of the furnaces illustrated will keep two or three hydraulic riveters going as fast as they can work, whilst it would take two or three small coke fires to feed one in the way suggested. Coke fires cannot be dotted everywhere

in a shop—there is no room for them; neither is an apparatus wanted which needs unremitting attention. Something wants inventing which will heat rivets as surely and expeditiously as present methods, but will *heat the points only.*

A method adopted in some shops is to take firebrick plates of various thicknesses having sixty to eighty holes through them, and through these insert the rivets over a coke breeze fire; but it is not satisfactory, since the chance of burning is ever present. An adaptation of this to a gas or oil furnace which maintained a stated temperature would be the ideal way, the great difficulty to be overcome being varying lengths and diameters of rivets and thicknesses of plates. To the ordinary muffle furnace diameters and lengths make no difference; all are pushed in the hopper for use as required without alteration or changing. It is more than probable that a compromise will have to be found somehow; it is of no use designing anything which will need the services of any but a boy—simplicity must be obtained; and so the problem stiffens. There are one or two furnaces which are reported as being able to do what is wanted, but nothing that has received such a testing or extended use as would warrant the statement that solution was arrived at. Coke fires are not reliable, and it seems as though their use for rivet-heating has nearly come to an end.

Many foremen and riveters, finding by experience that high uniform heats are not suitable for heavy pressures, put rivets in at as low a temperature as they can get the machines to work at. In many shops rivets at a little over black heat can be seen closed daily. It is the practical man's way out of a difficulty which he does not clearly understand, but it is only meeting things half way and is at the best a reprehensible practice. Those inspectors who insist on a 6-in. long, 1-in. diameter rivet coming out of the muffle well hot, and seeing it closed immediately at about 35-tons pressure, are far from aware of the results which will follow their directions. By all means see that the point is hot enough for a perfect head, but keep the shank as cool as is reasonably practical.

CHAPTER XVIII.

THE SMITHY.

For convenience of designation all steelwork (with the exception of rivets) which has to be heated before it can be worked may be deemed to be treated in the smithy, and the requisite tools can be described under this heading.

It is somewhat astonishing, considering the changeability of the times, how firm a hold the smith's hearth and anvil has upon our work, and yet it seems further off than ever now from being ousted. It still remains the chief and essential part of the smithy, and probably always will do. Many auxiliary tools have been added to the equipment, but nearly all in some way further and expedite the work of the anvil to which their products come for finishing. Certain work—best work—is still often made entirely throughout on the anvil, and on it the smiths of to-day are no better and no quicker than those of fifty years ago.

In constructional steelwork though, with its plainness and hugeness, it has been possible to devise many helps to rapid and economical work, and a modern smithy, or that part of the shops given over to heated metalwork, is not complete without many new or comparatively new tools. Amongst them may be mentioned the steam, pneumatic, strap, and hydraulic hammers, the hydraulic press, power swaging tools, welding machines, and special tools, formers and blocks for most processes. From the employment of hand-power alone, we have progressed to the use of hundreds of tons of load performing the former work of days in minutes and seconds.

It is seldom that any steelwork is so designed that it can all be worked cold, notwithstanding the obvious saving to be effected. Perhaps the most called for adjuncts to girder work are the cranked stiffeners or angles required, and a rapid and economical method of bending them is very necessary. Both joggled and kneed work used to be performed entirely by hand, strikers being employed to hammer into shape. Even now, if it is an odd size and perhaps only one or two wanted, this will be the best way; but for all repetition or standard work the hydraulic press is far before other methods. In small shops not possessing a press, blocks are used for kneeing and the section bent over them by hand. Suppose that a 5-in. × 3-in. × $\frac{3}{8}$-in. tee has to be kneed over a $3\frac{1}{2}$-in. × $3\frac{1}{2}$-in. angle, the blocks will either be

a casting shaped to the inside form of the knee with a groove cored out to receive the web of the tee, or two cheek castings which will be bolted together with a distance plate of the requisite thickness. Fig. 90 will show the blocks. The tees are heated at one end, as far up as is necessary, on the

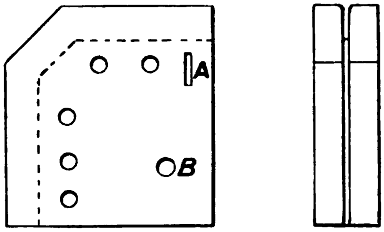


FIG. 90.—Block for kneeing.

hearth of a furnace, which is usually coal-fired, to a good, nearly white-hot heat. When ready they are withdrawn, and the hot end is laid on the block and clamped by means of a shackle and wedge at A. A long lever, forked at the end and prepared for attachment at B, and furnished with a

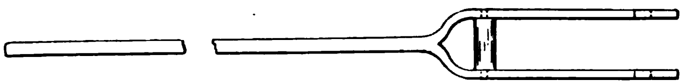


FIG. 91.—Lever for kneeing-block.

roller as in fig. 91, is then hastily pinned to the blocks, and a couple of strikers, seizing the round end, pull it down until the tee is forced around the block, somewhat as in fig. 92. The lever is then quickly taken off, and the smith uses his flatter, the strikers each swinging a sledge-hammer. So

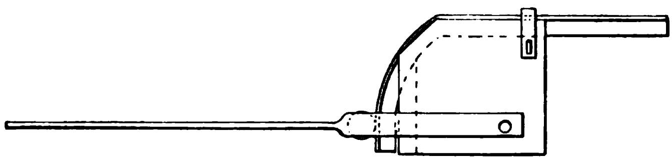


FIG. 92 —Mode of using lever and kneeing-block.

soon as the tee follows the contour of the blocks it is unshackled, and the web, which has perhaps buckled a little, is carefully flatted out and the knee set to template gauges in the ordinary manner. The other end of the tee then follows the same process. The work is hard and has to be quickly done, and is usually in the hands of special men known as "angle-iron smiths," who receive extremely good rates of pay.

Naturally such work is costly and is not now possible commercially, though there used to be no other way open. It is practically confined to small shops, or for odd jobs for which it would not pay to make tackle for hydraulic pressing.

Figs. 93 and 94 show different hydraulic presses specially made for stiffeners,

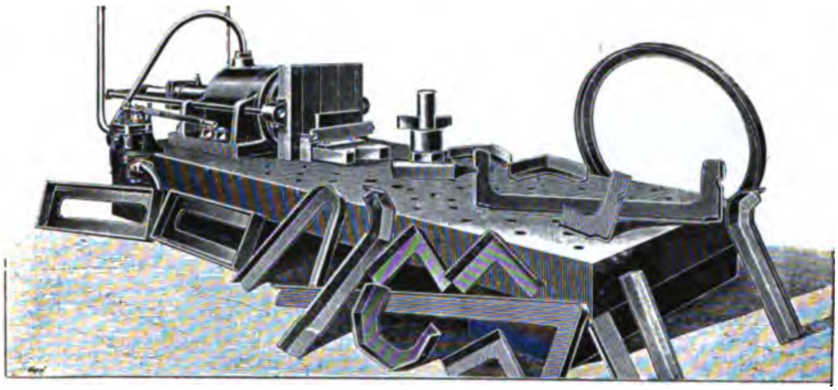


FIG. 93.—Hydraulic press and table for bending stiffeners.

etc., in which work costing half a crown by the old hand methods can now be made for sixpence. The horizontal press is much preferred, as it is handier than the vertical, though the latter can be obtained. One end of a stiffener

FIG. 94.—Hydraulic press for bending stiffeners.

is still done at once; but, with proper dies on the table, it is evident that when hot the ram will press it into shape immediately, and the web can be then flatted and trimmed into shape on the corner of the table without losing much heat, and in very much less time. A good furnace is wanted—some are gas-fired, others use coal or coke. The essential is that burning

should be avoided by keeping the metal clear of the fuel, and it is usual to heat on a clean hearth which is swept by the flames. By these means exceedingly rapid work can be done. The press should be of good power, according to the work expected of it. About 40 tons will be ample up to 6 in. × 3 in. × ½-in. tees. If heavier sections are to be dealt with, up to 70 or 80 tons or more may be required. A hydraulic drawback should be

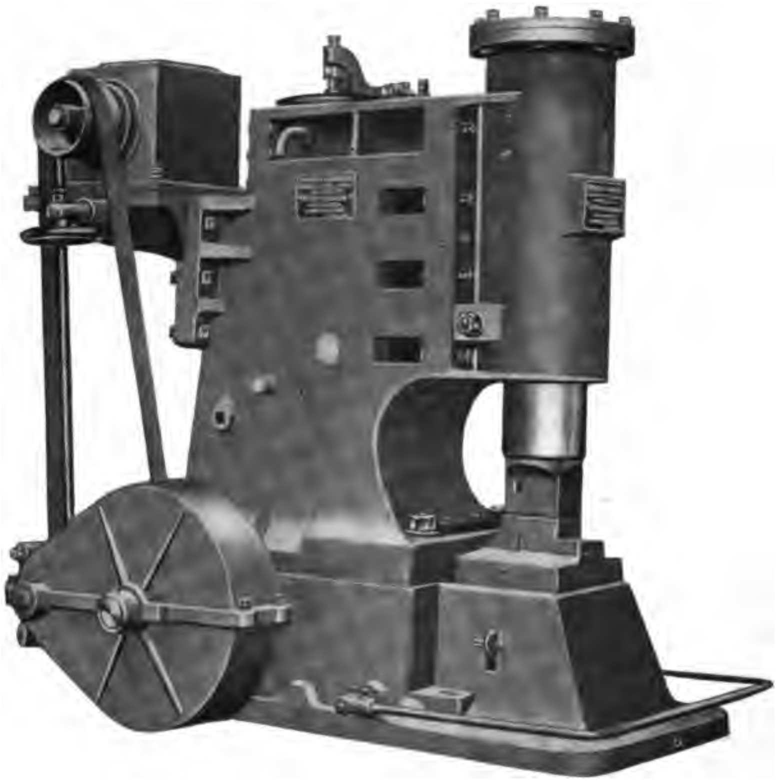


FIG. 95.—Electrically-driven power hammer.

fitted so that the ram may be at once retracted, and the table should not be stinted in size, and ought to be heavy and solid in section. A combination valve to work both the ram and the drawback is best, so that there may be only one handle. The supply pipes should be large enough to work the press at a fair pace; nothing is more annoying than a ram which crawls.

Angles may be bent at a right angle in one of these presses, without the necessity of cutting a vee out of the web, as is done by hand methods. Naturally the web is crushed and distorted, but if the steel is brought to a good white heat it is surprising how amenable it is, and the flatter will finish

it off to look quite neat. It makes a very much stronger job than cutting and welding, the slight thickening in the root adding stiffness. Any kind of bending may be done by the use of suitable blocks much cheaper than by hand, provided the blocks are in stock. If only one or two pieces are required to a special shape, then it will not pay to make the requisite tackle, and they are best made by hand.

Cold-bending and straightening are very often done also. The ordinary

FIG. 96.—Pneumatic hammer.

belt-driven straightener is often not powerful enough to do joist work and large section channels, etc. When such is the case, the hydraulic press proves very handy, its great power making light of even very stiff sections. It is in fact adapted for anything of this nature, and can even be arranged at a pinch to punch, shear, and weld. It is one of the handiest tools a shop can have.

Most smithies are now equipped with a power hammer; and as they are to be obtained of almost every known method of drive, one can be selected to fit the conditions of any shop. The ordinary steam hammer—so long the

favourite—has been to some extent superseded by the newer forms of strap and pneumatic hammers, but it is still, in good hands, capable of holding its own. Figs. 95, 96, and 97 are representative of what is now being used. All types are made in any desired powers; the small shop will only need a very light tool, whilst the larger ones will have one, two, three, or four, ranging from light to heavy according to the nature of the work they do and the output. Very heavy types are not necessary for steelwork, since the heaviest work

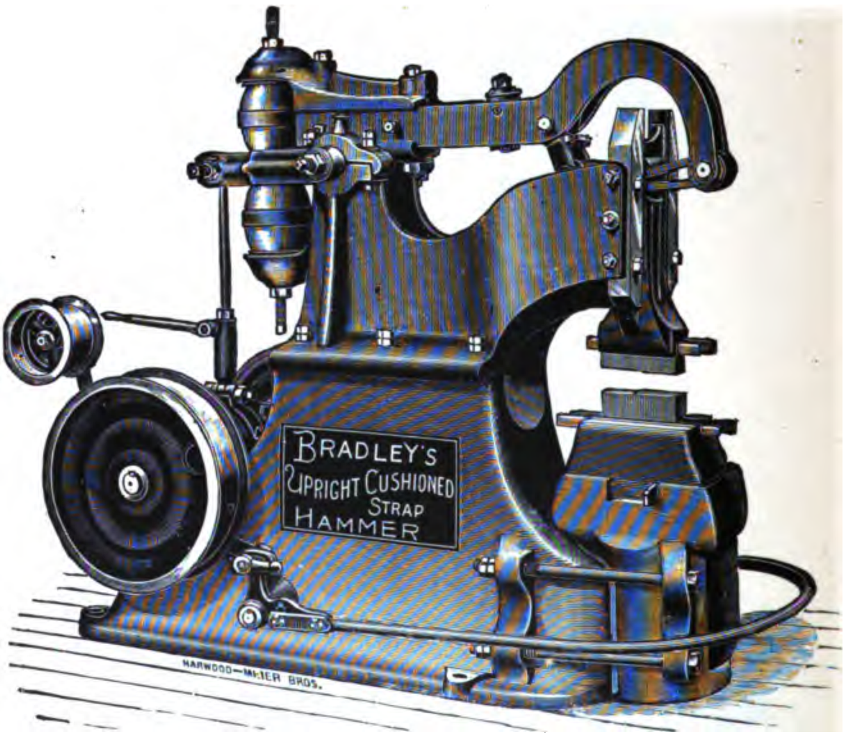


FIG. 97.—Belt-driven cushion-hammer.

they are likely to be called upon to do will be the forming of end-eyes and middles for roof-ties of perhaps 3-in. or 4-in. diameter at the outside. British shops differ materially from American ones, in that we have not the heavy eye-bolts and pin-truss scantlings to deal with that they have. Our riveted work needs very little smithing indeed compared to their pin bridges, and tools suitable over there would be utterly out of place here. Of course we occasionally get odd ones, or a suspension bridge with heavy links, or heavy forgings in swing, lift, and tilt bridges, etc.; but these are not the *average* of structural work, and it would not pay to keep either tools or men constantly employed for the sake of what might turn up once in a while. If heavy

forgings are called for occasionally, the best way is to get them made at places making forgings a speciality—both money, time, and temper will be saved, and a much better job result. Generally speaking, a 7 or 8 cwt. steam hammer and a 300-lb. strap or pneumatic hammer will be equal to ordinary demands. Hydraulic hammers are not much in use; modern ideas favour the short, sharp, rapid stroke of the pneumatic hammer in preference to the slower but more powerful hydraulic squeeze. Certainly the rapid stroke is more versatile and adaptable to a much greater range of work, and it is a pleasure to see a competent smith at the anvil.

The smithed connections in a round-rod roof truss are now usually made from stampings. Given properly shaped dies (often made from cast-iron when the number required off is not large), end-eyes, middles, and fork ends can be stamped to outline from bars of suitable widths and the right thicknesses, and then finished up partly on the anvil and under the hammer. The cost of the operations will depend altogether on the smith himself; some men will turn out quite double the work of others and of a much better finish. A frequent plan is to have set prices for everything, and then the only difference to the management will consist in the relative degrees of finish, and men must be selected for the different work according to the selling prices obtained. The payments made vary naturally according to the size of iron or steel being used, though as it gets bigger they seem to rise a little out of proportion. Thus a 1-in. end-eye can be made for 2d., a 2-in. for 5d., whilst a 3-in. will be 1s. 6d.; a $\frac{3}{4}$-in. jaw will be 9d., a 2-in. one 1s. 6d.; a 1-in. shut or weld will be 3d., and a 3-in. shut 2s. (by hand). End-eyes, middles, and jaws for principals are made ready for welding to the straight intermediate rods, which is a separate operation. Sometimes the pin-holes are put through them in the smithy, or they may be drilled, according to the specification demands The crucial points are always the welds, and as some men are better at these than others the maker of the forgings is not necessarily entrusted with their welding. Many attempts have been made to substitute machine for hand and hammer welding, but at the time of writing no great success has attended the efforts. An iron table of convenient height is furnished with sets of cramps or grips for holding each bar, and these are made to approach each other through the agency of a lever, thus squeezing the two hot ends together. For very heavy work there is some advantage to be gained by such a method, but light work cools too rapidly and is too small to be dealt with in any way but by hand. Again, if the work is really heavy and beyond the capacity of a couple of strikers or the power hammers in use, it should be done in a proper forge where men and tools are used to such work. There is not such a great demand nowadays for "all-round" smiths in shops. Work is cheaper when men specialise, and so the man used to turning out $\frac{3}{4}$-in. and 1-in. diameter work cannot be expected to be equally nimble with 5-in. or 6-in. work. In British works, only steelwork shops with a very large output ever touch jobs in which an amount of heavy welding is required, and as there are usually many more departments than these shops it is best to send the

heavy forging into the one most used to it. It is a mistake to lay out shops with the intention of doing this in the same place as the lighter work, since home work will not keep the tools and men going. In American shops hydraulic machines are very largely used both for forming and welding, and tools are in use which are unknown in this country; but they are not of interest to us, since we could not use them to any profit; they would be in the same relation to our class of work as nests of radial drills would be to

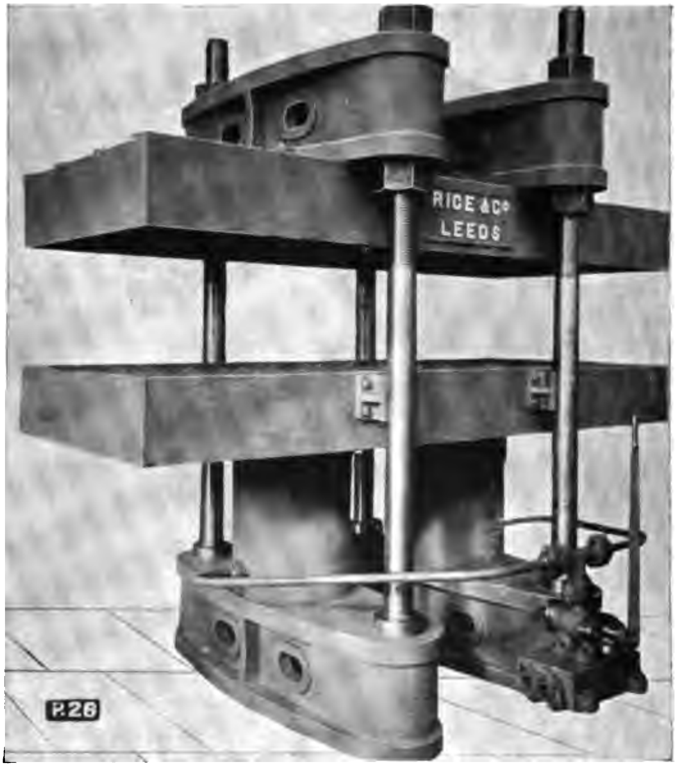


FIG. 98.—Vertical hydraulic press.

theirs. Besides which, current engineering sentiment is not in favour of welding steel for constructional purposes. It is rightly regarded that welds, and especially those of any size, should be avoided as much as possible and other available methods of construction substituted.

A very necessary tool in the smithy is a vertical hydraulic press adapted for the production of buckled flooring and bridge plates. During late years the tendency to employ pressed troughing has largely increased, and there is no doubt that it makes a most efficient bridge or heavy warehouse floor at a comparatively economical cost. It differs from the rail-bearer and cross-girder

system in that its strength is constant and uniform for the area. For road-bridges and any places where wheeled traffic is not confined to rails it cannot be surpassed; and as the use of the press in its production has led to endeavours to extend the principle, trough-steel guttering and pipes are now much in demand, whilst it is not improbable that in the near future steel linings for underground tubes and conduits may be employed. Most yards

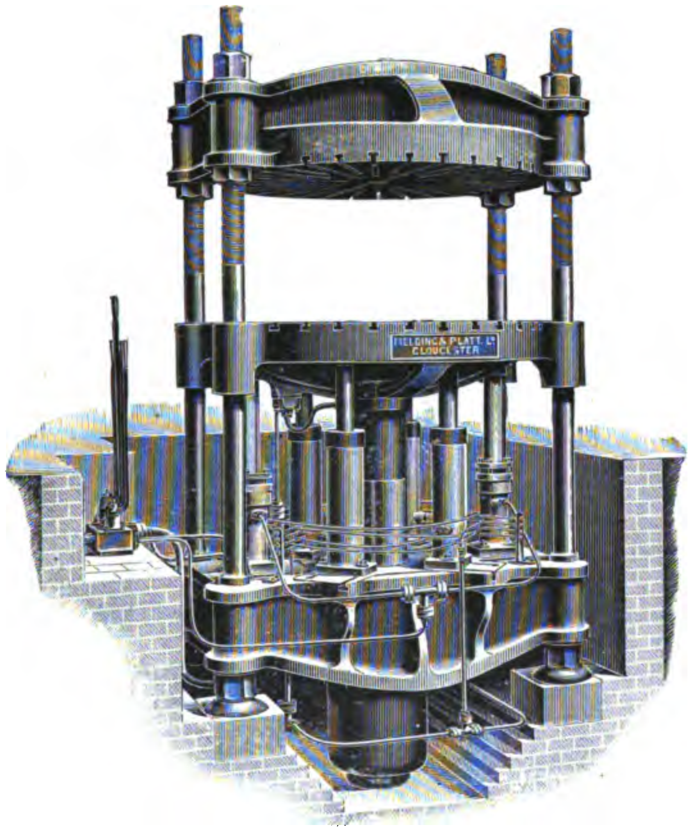


FIG. 99.—Vertical hydraulic press.

now have one or more presses capable of turning out this class of work. Figs. 98 and 99 illustrate the general design of tools suitable for making a variety of work. Specially made and designed presses can be obtained for quantities of any one thing for places making specialities, but the average shop requires an all-round tool such as those illustrated. A good width between standards is required, and also good "daylight" or lift, or else the size of the plates which may be pressed gets very limited.

Suitable blocks or formers are fastened to the top and bottom beds, and

the hot plate placed between, when the lift of the ram forcing the bottom table up shapes the plate according to the blocks. Blocks are not generally made the exact outline of the finished article—main dimensions are the same; but unless liberty was given for the plate to slip as the press closes, it would either be torn or else jam the blocks. For instance, if a trough section is to be pressed, it would appear between its blocks as in fig. 100, so that it is only in contact with them at just the places essential to its assuming the desired shape. The effects of contraction in cooling have also to be provided against; sometimes sections will open or close a little as they cool, and the blocks must be schemed so that due allowance is made. Occasionally special precautions have to be taken to ensure the cooling process being as prolonged as possible, and in all cases it is customary to shield the hot plates from wind and rain. Presses for this work should be of ample power, and are generally of from 300 to 500 tons. If large and heavy work is to be made, up to 1000

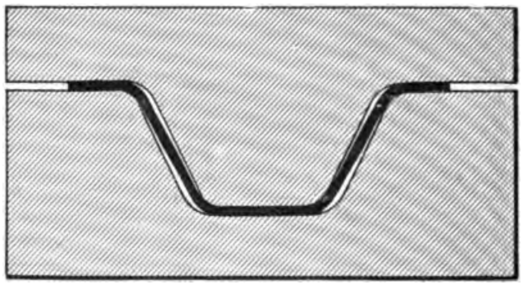


FIG. 100.—Trough section between blocks.

tons may be necessary, but the average requirements of a girder shop will be met by half that.

The furnace used for heating the plates is usually coal-fired and from 10 to 25 or 30 ft. long, according to what is required of it; the hearth is shallow, but of width equal to that between the press standards. If very long, in addition to the end fire it may be fired at intervals of, say, 5 or 6 ft. in its length, the object being to get as equable a heat as is possible. Three to five plates can be placed in at once on top of each other, and it will take perhaps half an hour to bring them to the right heat. The door being lifted, the top plate is seized by special tongs attached to a windlass by chain, and the plate is hauled out over guides and on to the blocks, where it is quickly adjusted in position and pressed. It is drawn from the blocks in the same way and deposited on the cooling ground; the operation is repeated until the whole charge has passed through the press. As the work is exceedingly hot and heavy whilst it lasts, it is generally conducted under open sheds or lean-tos. The labour is not skilled, with the exception of the leading hand or charge man, and when once the tackle has been properly set everything proceeds automatically and cheaply. Night and day gangs are the cheapest when the

work will warrant it. Once the furnace has been got to the proper heat it can be held there, but if banked for the night the continual expansion and contraction play havoc with it. Plates waste somewhat in the process; it is impossible to prevent a certain amount of scale forming owing to the action of the flames; care has to be taken to prevent burning, though the error is usually the other way on. The valves controlling the press must be placed within easy reach, and the men well drilled; one man to do this and another that, and then rapidity of working is assured. The press should stand in front of the furnace mouth with a sufficient space between to allow of the insertion of the cold plates into the latter; the distance can be bridged over by old rails when the plates are ready for pressing.

Miscellaneous smithwork, of which there is always a certain amount, is still done in the ordinary manner. Notchings of joist ends, angles, tees, etc., are best done by the cold saws, though many shops send them to the smithy. Bent plates, cleats, shoes, cap-plates, etc., will be done either on the anvil or in one of the presses, as convenient.

A small cropping shears is always of great use in the smithy. It need not be of the latest pattern—any old tool will do, as its use will be intermittent; but it will daily save valuable time if installed.

The smithy is usually the most neglected shop in the works as regards lifting and hauling tackle. So long as very light work only is done, of course none of this is wanted; but in most cases no provision is made for any, even if heavy work is being made. If pressed plates are to be turned out, cranes and overhead tackle should be freely put up, and the lifting and hauling labourer dispensed with as much as possible. There should always be lifting tackle for use at the hammers, and blocks available for slinging in convenient positions as required.

CHAPTER XIX.

FINISHING AND DESPATCHING—MISCELLANEOUS.

After assembling comes the finishing, marking for erection, and painting. Plain girder work will not want any of the first if it has been properly made, but there will always be a certain amount to be done to large open-web girders, roofs, etc. Careless work often results in gussets not being fair with flanges, kneed stiffeners overrunning, rivets which want dressing. Perhaps a few rivets have been put in holes which should have been left blank, or holes which ought to be elongated are round. It is the plater's duty to go over his job most carefully, comparing it with the drawings in every particular, so that any mistakes may be duly rectified. Dimensions should be checked throughout and a complete survey made; an hour or two spent this way will often save pounds on the site.

The inspector will now want to view the finished work; probably he has paid several visits during its progress and is conversant with it to an extent, or he may have been in residence. Anyway, it will be his duty to go over it thoroughly now, testing every part for agreement with the drawings and proving their truth by all methods open. If it is a bridge which has to carry a test load, arrangements will have to be made for sufficient weighty material to be placed upon it to comply with the conditions. Very often pig-iron is used as being conveniently handled; but built-up work to other orders and of known weights may be utilised, so long as the correct distribution of load can be managed. Bridges for which such tests have to be made are usually light colonial ones; it is obvious that heavy railway bridges could not be adequately tested in the maker's yard. The bearings must, in all cases, be specially looked to and provision made that the ground will carry the concentrated loads. If deflection has to be observed, pegs may be driven in the ground at intervals on which data can be marked. This is preferable to stretching lines, as their sagging tendencies are not present, and absolutely accurate records can be taken.

Inspection over, the erection marks can be put on and the general painting done. All marks should be in large white characters which shall have no chance of becoming effaced or indistinct. Letters are a favourite means, or a combination of letters or figures, and they should be at least 6 in. high,

or as large as the piece will hold below that, and boldly made. Stencils should be used, unless the man doing the work is exceptionally clever—strange hieroglyphics sometimes have to do duty when stencils are not available. Special directions, such as "This end next to B——," etc., for putting on girders ends, should always be cut out of stout brown paper in the drawing office or template shop and stencilled on. There should never be any lack of erecting marks; certain things may be very obvious in the shops when everything is together, but the case is altogether different when there are a score or more trucks on site, and nothing but a drawing to show how to reassemble the disjointed members they contain. Let there be a plurality of marks, so long as they are the right ones.

Painting may be either in oils or oxides, according to the specification, and put on either with the brush or by air. On large plain surfaces the latter will be the quicker way, and with careful men will require less paint, but all light work and open-webbed girders are best done with the brush. The operation will pay for looking after; a great deal of paint is usually wasted in most yards, especially when payment is by the ton. There is a certain advantage in piecework, admittedly, but there is more in weeding out the wrong men and keeping steady hands who can be relied upon at a day-work wage. The paint bill will be less anyway, and it will rest with the foremen and manager as to whether each man is earning his pay or not.

Taking apart and packing are the next duties. For home orders the latter will be almost a negligible item, but foreign work—especially Crown agents and Admiralty—wants a lot of time and trouble spent upon it. The flange and diagonal ends at each break joint will have to be protected with stout boards and battens from the chance of injury during shipment, and all loose rivets, bolts, and small parts packed in strong water-tight cases. There will be a lot of work for the carpenters, whilst the shop foreman must see to the proper counting of everything, including the extras, as per specification. Special stencils will have to be cut both for the girder work and the packing-cases—some places cut them out in thin zinc so as to last longer—and it will be found the best policy to carry out to the letter the many stipulations made. If there is a siding into the works and own trucks are being used, the loading must be carefully attended to, and whether for home or export there cannot be too much attention paid to the securing of the girders. The curves on British lines are of so small a radius, and there is so much shunting carried on, that light work especially is often damaged by being bent in transit. When long girders rest on two or three points only, perhaps hanging over the end supports some feet, it is a serious thing if the chains slip and let them slide, even if ever so little. Damage is bound to be done, and attempts must be made on the site to rectify it, resulting very often in obviously straightened and unsightly places, perhaps leading to trouble with the engineers. Loading is a particularly awkward job, and should always be in the hands of a good man, who should be fairly well paid.

One of the most important points in loading is that there shall be ample

power available. In assembling, pieces are usually small and light tackle may serve very well; but when completed girders or large portions of them have to be bodily lifted, heavy cranes are necessary. Consequently the heaviest tackle will always be over the erecting spans, and the loading-stage or siding should be so arranged that they can pick up the work and put it on the trucks without further handling. In works of any size it is usual to have 30- to 40-ton cranes—generally overhead travellers—to do this, but it is really seldom that their full capacity is taxed. Thousands of tons of work may be turned out and no lift over 10 or 15 tons experienced; but there will come the necessity, and if the power is not there an awkward time will be gone through. The best way is to arrange the crane power so that ordinary loads—say up to 15 tons—can be handled at a fair speed of both hoist and travel, having the girders carriage ropes, hook, etc., strong enough to sustain a 40-ton load, and the engine power sufficient to lift, traverse, and travel it at a very slow speed only. Since the big loads are comparatively so seldom met with, nothing will be lost by very slow handling of them, so long as handling is possible. There will be more gained this way than by providing a crane which will deal with a 40-ton load as though it were a feather, and then keeping it working every day but one in the year on loads of less than 10 tons.

The question of the size of pieces which may be sent by rail is often an awkward one. If for export, generally that which will pass for shipment will be right for the rail; but home orders are often awkward, in that it is generally desired to send the largest possible pieces, and whilst the main lines may carry them all right, some local ones, or one of the smaller companies, may have a curve which they will not safely pass or a tunnel which restricts the loading gauge. All sorts of ways have to be resorted to in order to save sending away in small pieces with the resulting extra work in erection; a good deal depends on the trucks selected, but a knowledge of loading gauges is absolutely essential. When loading for safety and also to a gauge has to be considered, the problem is not always an easy one.

The first thing to consider in breaking up for despatching is the way in which erection is going to be conducted, and the handiest sizes and pieces for handling on site. If the job is a bridge on a new line, then the only consideration will be the lifting tackle available and the approach to the site; if a road-bridge, perhaps an amount of carting will have to be done from the nearest railway station, and the sizes of the pieces will then be necessarily very limited; if over a waterway, the condition of and accommodation on the banks may exercise great influence; if for a warehouse or building, the approach and the room for lifts may be exceedingly limited; in every case conditions on the site will vary and due account must be taken of them. Then, when the most economical method of erection has been determined upon, it must be ascertained whether the selected pieces will pass the loading gauges, and perhaps further slight modifications may be necessary. Bridges and all erections which are broken up and sent away

without due thought as to this may often prove expensive examples of how not to do things.

There are one or two points of manufacture which could not well have been dealt with in previous chapters, and which it will be as well to mention now.

When making stanchions it is, of course, an essential that the base-plates should be square with the shafts, and also that all the material of which the shafts are built should have a fair bearing on the plates. To ensure this it is often specified that the ends shall be faced. Now, if the stanchions are small, this will not be a very serious matter—they can

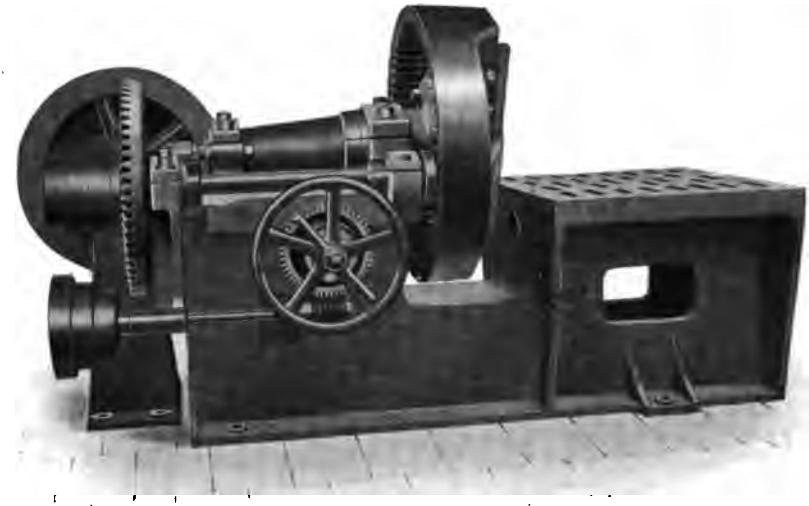


FIG. 101.—Girder-ending machine.

be readily put in the lathe. But lathes are not usually common tools in a steelworks, and if the stanchions should be large and unwieldy—say something like 57 ft. in one length and weighing about 20 tons, as in the case of some lately put up in the Midlands—it would take a larger lathe than ordinary to deal with them. To meet the difficulty tools have been designed which are known as "girder-ending" machines, and they are equally suitable for large and small work. One is shown in fig. 101. Instead of chucking the stanchion and turning it round whilst a stationary tool does the facing, the stanchion or girder is at rest, being brought up to the face-plate and placed truly horizontal and in line with the machine, either on runners or low bogies or other suitable device. The knives or blades fixed to the face-plate, which is actuated by massive gearing, then quickly do the required facing, the operation not occupying a quarter of the time it would take a lathe to do it. One such machine will keep a

large shop going, unless much of the work is joist or compound girders; when this is the case, it is, perhaps, cheaper to put them together without cutting off to dead lengths, doing this when riveted up, in the "girder-ending" machine. In fact this type of tool was originally designed for just this work. Most girders made up of joists and with flanges riveted on have these latter made from flats. Both joists and flats can then be picked up just as they arrive at the shops and be put together without going near the planing machines or the shears, being faced to correct lengths in these machines when riveted up. There is a distinct saving here, and for builders' steelwork the tools are excellent.

They are practically very powerful lathe headstocks set solidly on good foundations, with a heavy face-plate which carries the knives. They naturally absorb a great deal of power, but when it is remembered that on a certain class of work they practically supersede the planer and the shears, this cannot be complained of. A "joist" yard or shop where builders' work only is done could almost dispense with these two tools, given "girder-ending" machines. If the work is properly set, they make a perfectly fair end, and their advantage in stanchion work will be patent.

A tool that is often of service is a good shaper. It should be perfectly plain, and arranged so that work may be fixed either vertically or horizontally, and have good-sized beds. It should be a heavy tool, capable of taking a good rough cut—engine-finished work will not be required of it, but it must be quick and durable. It will be useful for the occasional awkward fitting which has to be done, for slotting and easing, and would be all the better for having a couple of heads.

During late years much has been thought of "Dr Angus Smith's solution" for coating and protecting against oxidation. Its principal use is for cast-iron pipes; but steel pipes are now coming much to the front, and the hydraulic press being handy for making them, girder shops are taking up their manufacture—some as a side line, whilst others make a speciality of them — and the coating is proving of equal service for them. There are many recipes for the solution; the following being accounted a good one:—

6 gallons tar. 2 ,, prepared oil. 1 ,, paranaphthalene. 4 lbs. tallow.	7 lbs. pitch to be added if desired thick.

The only successful way of applying it is for both the plates and the solution to be hot, and for dipping to take place. Application with the brush is a failure. For it to be lasting and give the maximum of protection, the plates should be dipped before they have got quite cold from the pressing, or if they have become cold they must be left in the solution until they have reached its temperature. Usually a tank of sufficient size to properly take the intended articles is filled with the mixture and kept hot by a fire under it, or by being placed over a flue. The bent plate is

lowered into it and left there until it is of the same heat, when it is hoisted out and left to drain for a few minutes on a rack which slopes to the tank. When set it can be stacked away. It is of no use just dipping a cold plate in even the hottest of solutions: it will look nicely coated perhaps, but there is no real bond between the metal and the tar, and the protection is no better than common paint. The plate must attain the same temperature as the fluid; the coating is then very thin, but it seems to be part and parcel of the metal itself and is practically indestructible.

If much repetition work has to be dipped a big tank will be necessary, so that cranes and men may not be kept waiting at all. It should be of sufficient size, so that when the last article has been placed in the first is

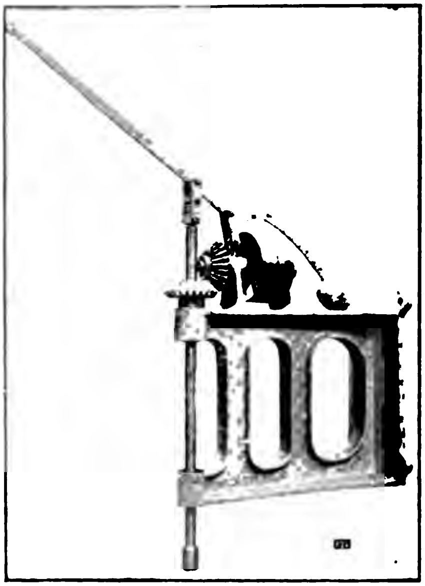


FIG. 102.—Countersinking tool.

ready for withdrawal. A power travelling crane and a couple of labourers can then get through an astonishing amount of work in a day. When well and thoroughly put on there is no known agent to compare with "Angus Smith's solution" for durability and service.

For countersinking rivet-holes a useful tool, if the shop is laid out so that it can be used, is a wall-bracket drill (fig. 102). It is very rapid in action, and a boy will get through a great deal of work with it. It is not suitable for all works, since the job must be taken to the tool, and that is not always easily managed, many shops finding that the pneumatic drill, or even hand-tackle, pays them best. Everything depends on the *amount* of countersinking to be done. If there is not more than the little which occurs at girder bearings, it is not worth while putting up wall drills; but if a lot of,

say, flush-riveted tanks or doors or other work is done, then the arrangement of the countersinking tackle becomes as important as the drilling or punching. In such cases the wall drills should be so placed that as jobs leave the drilling machines they pass under them. The machine shown is quite elaborate enough for everyday work, is inexpensive, and very unlikely to get out of repair. If, however, the surfaces to be countersunk are large in area, and so are unwieldy to move about freely under the tool spindle, then they are best countersunk in the drilling machines, as it is evident these small tools can only be used for easily handled work.

There have at various times been many special tools devised for lessening the number of operations and settings of work. Few of them, however, have survived. The first one or two machines have been placed on the market with much beating of drums, and pages of figures have been adduced to show the great savings effected. Tools weighing well into the hundreds of tons even have been put down in the confident belief that they will soon pay for themselves. It is only experience which disproves the sanguine estimates formed. The real difficulty with steelwork is that no two jobs are precisely alike. Bridges will not come in with main plate girders 60 ft. long and 5 ft. deep—or any other standard sizes. They persist in never being exactly like any other ever made! It is very hard on the tool designers and specialists, but facts are facts, and one might as well wish for the moon as hope that things will change. It would, for instance, be a very fine thing to put a flange together on a long bed—say 50 to 80 ft. long, with spare sections so that it could be made even longer if required—and either drill or reamer the holes with one or a number of tool-heads and plane the plates with another one; or, to take another case, punch all holes small in flanges and webs in the usual way, assemble the girder, and then place the whole thing on the bed and reamer all holes and plane all flanges. It looked so before it was tried; economies were easy to see, and plain girder work was to be turned out wholesale. But when the tool was made and tried in actual work the difficulties cropped up. The saving proved to be less than was expected, and there were practical obstacles in the way of fastening down a whole flange sufficiently securely for planing purposes, whilst the power necessary seemed out of all proportion to the work done. It is a lamentable fact that theory and practice do not always go hand in hand, and perhaps no one is so fully aware of it as a machine-tool builder.

It is therefore wise to be a little chary of brand new combination tools or ideas. It would be folly to say that they are and must be always bad; possibly a very short time may see quite a revolution in our present ideas of the trade; but possibilities are not necessarily probabilities, and the chances are that the single tool will continue in the future, as in the past, to be the best yet made. For these reasons the author has refrained from illustrating any but well-tried and approved tools, which have by constant and wide use demonstrated their necessity and their claims to consideration as "standard" machines.

CHAPTER XX.

GENERAL EQUIPMENT.

In a previous chapter a few notes were made on the modern practice of doing all work under cover, and reasons given justifying it to a very great extent. It is not too much to say that all firms now working with open girder yards more often wish they could roof them over than they are pleased with existing arrangements. This is shown by the fact that modernising a works invariably means its reconstruction on the covered-in plan, and there are many acres of ground now roofed-in which ten years ago were quite unprotected from weather variations.

It may therefore be taken for granted that shops have really displaced yards, and that the wisdom of capital expenditure in roofing has been established. That being so, it becomes imperative in laying out new works to most carefully consider floor plans. It is a very different thing building shops to contain tools and work, to simply putting down a few tools under sheds fringing a large open space. A mistake in the one case may be fatal; in the other it will be of little moment, since a few pounds will soon rectify it.

The general policy here, as also in America and on the Continent, seems to lean towards the construction of large shops capable of housing the tools and all normal work, and the reservation of an amount of open space, where it can be managed, for jobs requiring perhaps more head-room than the ordinary, or with other abnormal features. If land is not very limited, such a plan has many commendable points, and is certainly the right one to follow; but when every yard is precious and has to be made the most of, it will be better to roof the lot to suit the average of work, leaving the abnormal to more fortunately situated competitors. Firms with their works in large towns, who cannot for some reason contemplate moving out where land is cheaper, cannot obviously afford to have a single square yard that is not actively engaged in earning money; the question of a yard being provided which shall be used perhaps one week out of the fifty-two is not for them—every unit must be of service for every week of the year.

The consideration of what shall and shall not be provided is not a light one, and demands intimate knowledge of the trade and of the special portion of it it is desired to cater for. A joist shop, or place where structural work

is made, would be laid out very differently to one dealing with constructional work, and a difference would again be made for a mixed shop. In fact, every class of work would need a modification in the provision for its execution if it was desired that that particular class should be made as cheaply as modern practice renders possible. The site again is bound to exercise great influence in the planning, and what might be possible and most desirable for a certain class of output is often rendered out of the question by prevailing conditions. Anyone who aspires to lay out a steelworks must not only possess a certain measure of architectural skill, but must also be conversant, and intimately so, with every aspect of the trade; he must be a practical workman gifted with an employer's financial skill and judgment, and an engineer in the broadest sense of the word.

One of the commonest mistakes made when laying out new shops is the outlay of more capital than is actually required. In the abstract every man will agree that to do so is sheer folly and sure to lead to ruin, but few men can resist the temptation to put in "the best of everything" when the capital at their disposal admits of it; few men can put in just that which will do the work perfectly satisfactorily and earn reasonable increment when polish and show and ingenious mechanisms are temptingly displayed. The whole secret of the successful conduct of a business lies in the employment of only that which will earn the largest percentages on its capital outlay. Every penny more than the absolute requisite minimum invested is but a drag and a handicap to the useful pence, and, as such, is a direct deterrent to progress. When a man or a company engages in any enterprise, it is usually done from a desire for gain; there may be much honest pride in the work turned out—that is not in any way incompatible with a desire for gain—but the primary object is interest on capital. That being so, it follows that the smaller the capital which must be embarked for a given purpose, the more lucrative the results will be. One may often see solid walls and foundations being built, which look and are calculated to be able to defy the action of time itself, and yet there is nothing to show but that in the space of a generation the whole erection will be out of date, behind the times, and of no further use for the purpose for which it was erected! Fortunately it is not so with everything; there is plenty of engineering work done which will remain a monument for all time to the skill of its designers and the men who laboured thereon; but processes of manufacture are essentially unstable, uncertain, and changeable as the seasons; a decade may see both the birth and the death of methods which, for a short year or two, made a world wonder; they are not suitable for attempted perpetuation, and it is money sunk to do more than provide adequately for the moment.

This is specially so with the steelwork trade. Fifteen years ago mild-steel bridges were practically unknown; wrought-iron was the material in common use. Fifteen years before that cast-iron bridges were still being put up; what will be done fifteen years hence, and how shall we be working? The girder shop of to-day—the modern shop in line with the most

advanced practice—was quite non-existent a couple of decades ago; it is just as likely that in its turn it will be superseded by other ideas in twenty years' time. We cannot build works and define the scope of industries for posterity—the march of progress will not be arrested for the sake of a few bricks or machines. So far as the outlook goes, it seems as though mild steel was destined for great things—that the world will get to depend more and more upon it, and that it will before long be vital to both trade and home life. But it would be unsafe to prophesy so, and rash to stake everything upon the chance, sure as it seems. The metal has some very well known drawbacks, added to which the science of construction is daily advancing, and already types common a decade ago are obsolete to-day: who can tell where all this is to land us, and will undertake to accurately sketch the future? One has but to breathe the words "concrete steel" to already cause makers to look askance.

Such as it is, however, we have mild steel with us to-day, and a large demand for it to be satisfied. New works must be put up, old ones modernised, and the times properly catered for. Money is to be made—and fairly good money too, in spite of competition, fair and unfair—by the shop which is well put up, well laid out, and well managed. The better it is put up and laid out, the more money can it earn; but it must be the "betterness" understood by all-round considerations—not merely the betterness of solidity and money spent. It is not the amount of gross profits a place may make which alone pays the dividend, but the ratio existing between the profits and the capital expenditure. £10,000 profits may be handsome in the one case, and not enough to pay 1 per cent. in another. Five per cent. depreciation on tools is barely enough as times are, and those firms refusing to reckon more than 2½ per cent. and 3 per cent. will find themselves "left" at some future day.

As the trade goes, all buildings and accessories should be subject to at least 5 per cent. depreciation charges. It is not safe to look further ahead than twenty years, if indeed that time is not too long. Many American firms reckon 7½ and in cases even 10 per cent., whilst the latter figure is a frequent allowance on tools. If percentages such as these are at all necessary, it follows that the shops need not be put up to have any longer a life. Bricks and mortar have only just begun to be of service, comparatively, in twenty years' time, and they are consequently unsuitable for a steelwork shop. If at the end of that time remodelling be necessary, a vast amount of money has to be sacrificed, since 5 per cent. depreciation on good brickwork is ridiculous and would always swallow the profits. A further argument is that the height considered necessary so as to give proper head-room involves such substantial walls that cost becomes almost prohibitive.

Steel framing is undoubtedly the system *par excellence* on which shops should be constructed. It is light, comparatively inexpensive, does not require difficult foundations, and if kept in good order may be rearranged in another plan at any time. It affords facilities for the attachment of cranes, lifting and running tackle, etc., possessed by no other constructive agent,

besides being proof against the effects of vibration. Any sort of covering may be used with it—slates, tiles, brick panels, corrugated iron, wood, etc., or it may be wholly or partly glazed, and is thus exceedingly adaptable. Perhaps the favourite covering is galvanised iron, and undoubtedly it possesses many advantages. A fairly light gauge may be chosen—22 gauge for roofs and 24 gauge for sides—and then cheapness is secured; yet, if well painted, it will last more than the twenty years desired. It is lighter and less expensive than slates, both in cost and erection, whilst being equally weather-tight and serviceable. An objection often made is that it is noisy and sets up reverberations at every hammer-stroke. There is an amount of truth in this, but the defect can be almost eradicated by laying or hanging the sheets to timber purlins, or interposing common felting between the sheets and the steel framing. With large shops well put together, noisiness is not really so noticeable; it is the hastily thrown together, loosely jointed structure which does the most chattering. Corrugated iron has been very undeservedly much abused; used properly it is a most valuable agent, whilst its life is quite long enough for the structures for which it is suitable. It has a reputation for being hot in the summer and cold in the winter. Steel shops should be so made that the wind and air can blow freely through them on hot days, whilst on cold days, if a man's work will not keep him warm, he is no good to the management; so long as the rain, snow, and keen winds are kept out in winter, and a man can work with dry material in dry clothes, he will not complain much. This is hardly the case with machine hands; their section should have some means of artificial heating, such as will be discussed presently, but the big erecting spans are too large to warm properly—a certain amount of warm air will find its way there, but the best warmth is a man's labour.

Timber would be a good and cheap covering for all parts where there were no fires; in fact wood acts very well for small shops, both for covering and framing, but the risks are great—insurances are high and so it is little used except for small lean-tos or temporary purposes, or in combination with corrugated iron. It is a pity to put slates or tiles on these shops; the capital cost is heavy, whilst they may have to be taken down before they have seen a quarter of their natural life, with the inevitable result of a large broken and spoiled percentage. So far as can be judged, the modern shop should be erected on those lines which shall ensure to it a life of full twenty years, yet at the end of that time be good enough in its framing to be rearranged and set up on other ideas, or again recovered according to the signs of the times; whilst it should at all times be ready for extension and growth in any direction. Steel framing with a corrugated covering gives all these desiderata at the cheapest possible cost. A little can be taken down here and a little more put up there at a trifling expense, yet with no sacrifice of strength or rigidity; but, probably, a gain thereof.

From what has been said regarding methods and tools of manufacture, the ideal plan will have been gathered—a "continuous" arrangement so that work is always steadily flowing in one direction, with the minimum of back or

reverse flow. The same piece of metal should not travel over the same ground twice, neither should it have a zigzag course; but as far as possible its progress should be in a straight line. Plenty of shops are to be seen—and recently put up ones too—where the punches and the drills are as far apart as they could well be placed; often material has to be carried past the cold saws to get to the straighteners. Bad planning of this nature will never turn out the cheapest work; everything must be disposed to the utmost possible advantage, so that handling may be reduced as far as possible. Whether keen competition has or has not to be faced, there can be no sense in doing unnecessary labour. Once the broad scheme has been settled it will not be possible to alter it, short of reconstruction. Minor alterations may be made; but a hastily thought out plan is bound to be bitterly repented.

The site is bound to be a governing factor; one cannot make a rectangle if only a triangle is available. But if the works are being laid out afresh on plenty of land, then one can strive to get as near the ideal as possible; if on a town site, the problem will be to make the best use of what room there is. It would obviously be impossible to discuss a variety of differently shaped sites; neither would it be profitable. The best way will be to indicate what appears to be the most favourable possible disposition for a medium-sized general shop, leaving the reader to determine what modifications must be made to suit other given circumstances.

First of all, railway tracks or sidings must be considered indispensable, and there must be at least two of them—one for the incoming and the other for the outgoing material; they might unite in the one track where they join the railway. Material should be unloaded on one side of the shops and the finished work loaded up on the other, so that one line will have to take a big loop or curve past the ends of the shops—preferably this should be the raw material line. To obtain the best results and expedite handling, they should be in shallow cuttings, so that the wagon bottoms will come level with the shop floors. It is not a big job to secure this, and is worth the little extra trouble and expense; it is more important in the case of the loading than the unloading dock, and if preferred the latter need not be done so. There will be less difficulty in cutting for the loading line, since it will be the straightest and most direct, in order that long girders may not have to travel round sharp curves.

Commencing with the unloading dock, there must first be space for the storage of the materials, and it will be convenient for it to run the whole length of the shops, as by this means the storage ground need not be wide. Few firms keep any stock of material, except those who possess their own rolling mills; but a little is always an advantage, and in those cases where it pays to keep some a shed for it will come the other side of the line, since only material required for use will come on the shop unloading dock. If we reckon that the largest girders to be made will be about 200 ft. long, our shops must be at least 300 ft., and this would be the length of the dock, with a width of from 16 to 20 ft. As the plates, angles, tees, etc., are

unloaded, they will be sorted to their particular jobs, and a light, quick travelling crane will be found very handy. If we provide that the dock is covered with a cantilever roof carried off the stanchions of the first main span (see fig. 103), this crane can very well be of the hanging-jib variety, running on top and bottom rails carried by brackets on the outside of the stanchions, and it will thus help to serve the straightening and planing machines as well. Its average lifts will perhaps be 5 or 6 cwts. each, but it may have to deal with loads up to a couple of tons in weight, and so will be best with two travelling traversing and hoisting speeds, one quick and the other slow. The drawback to a crane of this type is that a careless driver could soon wreck it and perhaps seriously damage some of the stanchions. An alternative would be a light locomotive crane running on rails laid just in front of the stanchions, but the smoke and heat are objectionable in a shop and it would have to be electrically driven, giving a nice problem to be solved as to the best method of driving. The only other way would be to do away with the cantilever roof, and put up another span, one resting on columns the other side of the rails, these latter thus running under the roof. An ordinary span travelling shop crane would then be used, and would serve the purpose very well, except that it is not convenient for passing material from the dock to the machines in the next span. Small hand cranes, whether of the jib or cantilever type, are not to be recommended. They will lift all right, but they are too slow in slacking and depositing. Overhead runners should be installed whatever crane may be selected, as they are so handy and quick for all light lifts.

In the next span are arranged the straightening and bending machines, those for the planing, shearing, and cropping, and the cold saws. In order to get the maximum of work from each, they must not be cramped together, but plenty of space allowed between them. There is as much virtue in having room to work in as there is in having the tools to work with, and a special point must always be made of seeing that there is "elbow-room" everywhere. The straightening and bending rolls—one three-roll and one seven-roll—and the sectional straightener will be next the unloading dock, together with the joist shearing machine and a small cropper. Behind them will come the planers, shears (plate and angle), and cold saws, the smithy taking up the rest of the length of the span, and divided from it by a partition, largely of glass. This secures the advantage of having the smithy next to the raw materials and close to the cold saws, avoiding extra handling, and also admitting of plates for pressing being unloaded direct against the presses. There must be free communication between the smithy and the shop for the unobstructed passage of materials. The hydraulic presses and furnace will be next to the dock, and inside them the bender, small tools, fires, and anvils. Running the length of the span will be a girder travelling crane, which should be of 3-tons capacity, fast and quick at its work, supplemented by overhead runners with cross-overs to the runners in the unloading dock. The overhead runners will do the normal light

To face p. 224.

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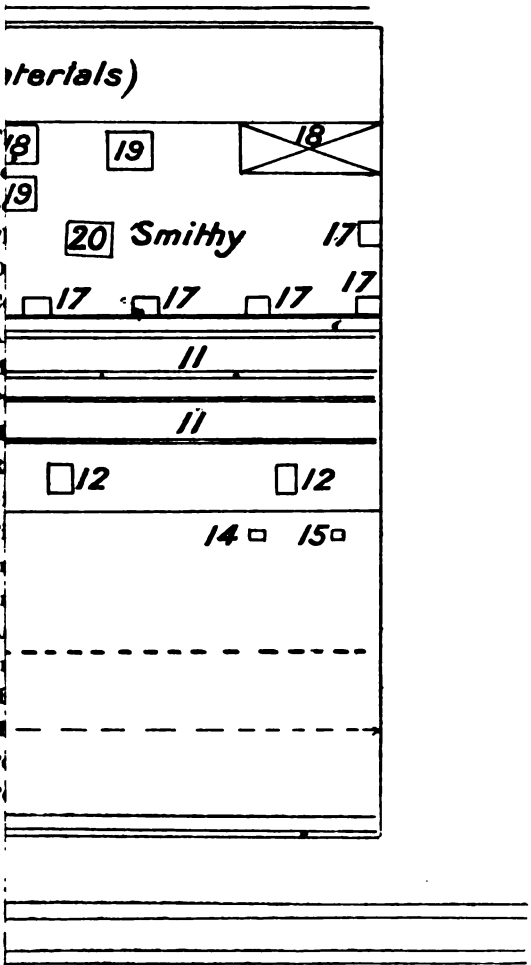

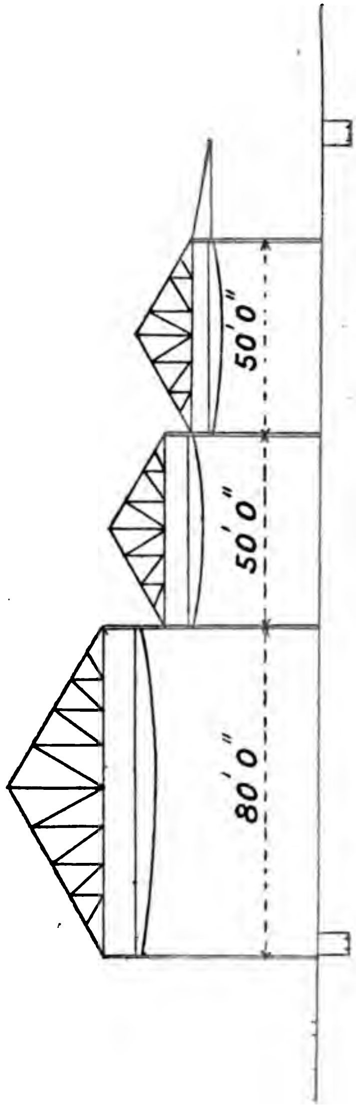

n-sized steelwork shops.

work at the rolls, planers, and saws, whilst the crane will serve the presses, handle the heavier material, and do the lifting from machine to machine. This span, like the unloading dock, will not require to be of great head-room. If there is 15 or 16 ft. clear under the crane, that will suffice; more height only means more cost and gives no corresponding advantages. 50 ft. wide will be ample and give sufficient space between the different machines, since whilst *enough* must be had, yet more would only be waste.

In the next span will come the marking-off tables and floor, the single and multiple punching machines, the gangs of drills, and the girder-ending machines, arranged in sequence, so that, as the material is marked off, it passes to the punches, and thence to the drills. If much drilling from the solid is anticipated, two nests of six each will not be too many, though one nest of six and a multiple or two can be used if preferred. The weights to be dealt with will be heavier here; the four bogie tracks to the drills will be about 80 ft. long, for the purpose of building up flanges, etc., and the crane must be capable of dealing with corresponding loads. It is a very awkward job to lift a drilled flange if of any length, and transfer it to the large assembling shop for incorporation in its girder. It wants well service-bolting together to hold the plates from sliding the one on the other as it is lifted, but even then it bends to a remarkable extent. A couple of lighter cranes are better than a single heavy one, and as in this span small and medium plate girders can be assembled, either on the marking-off tables or on the drill bogies or on the floor under the drills, and made ready for the riveting in the large assembling shop, the cranes must be capable of dealing with loads up to 10 tons. If one 10-ton and one light, fast 3-ton, having fast and slow gear, be provided, most contingencies will be successfully met. Overhead runners or light jib cranes over the punching presses and the light work marking-off table will considerably facilitate work. The span may be as before, viz., 50 ft., and the head-room may again be low; perhaps if anything it should be a little more, since there will be assembled plate girders to deal with, and plenty of clearance is wise when handling them; about 20 ft. clear under the crane will be suitable.

The assembling or erecting span will be practically clear of tools, except for the riveters, chippers, hand-drills, etc. One or two wall-drills with good clearance are an advantage for some work, but the main idea is a large clear space for its proper assembling, riveting, and dressing. Any tools brought in will be for the sake of handiness, and because the jobs usually done demand them; modern ideas favour the machine processes being kept as separate as possible from the putting together ones. The chief considerations in this span will be the width and height, and they will have to be regulated by the class of work to be done. For a general shop, 80 ft. wide by about 25 ft. under the crane will be enough, this clearance being ample for all ordinary girder and roof work; anything demanding more is likely to want so much that it would not pay to construct the average shop to hold it. The roof might perhaps be carried higher, so that a big dome or other work could be built

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round a pole at one end, dispensing for the time with the crane at that part. Many erecting spans are made wider than 80 ft., and of course in cases it may be advisable, but this figure will allow of a long-span double-track railway bridge being laid down, with plenty of room for miscellaneous jobs besides, and will be large enough to cope with the work turned out by the machine tools in the ordinary course. Hydraulic or pneumatic mains will be laid the length of the shop, and the loading siding should preferably run the length at one side also, this being better than running it outside the outer row of stanchions. Where space is no object, a gantry may be run out at one end in continuation of the crane track, and over which the shop crane can travel, the loading up being done here. But it is a question solely of the site; it is handier to have it in the shop for many things, but on the other hand it means so much valuable shop-room not being available for erection. It is important that the heavy travelling cranes be able to do the loading up, so as to save double handling, and so this is generally sought to be schemed. As previously mentioned, the crane, or cranes (there should be more than one for the best results), must be able to handle heavy loads, but this need only be at a slow speed.

The question of the supply of power to the different tools—straighteners, planers, saws, punches, drills, etc.—is one about which there are at present many opinions. In the old days, when the material to be worked was in only very short lengths, it was possible to group machines together and drive from shafting in the old fitting-shop method. Tools were placed almost on the top of each other, to use a figure of speech, and there is still no question but that given moderate lengths of shafting with good bearings, the system remains the cheapest where continuous work has to be performed. But modern practice has so changed the aspect of the shops that altogether fresh problems have now to be tackled. There must be big spaces between tools, because of the long lengths now to be handled. 40-ft. long plates are comparatively common, and if these have to be put through straightening rolls, it is plain that room must be given for it to be done. So with everything else; tools are long distances apart, and shafting from one engine has ceased to be a practical method, except in the case of very small shops. In its place we have offered us electrical drives, separate engines for each tool, and several engines each driving small groups of shafting. Oil, gas, and steam are variously used, and a central generating station. Experience, so far, seems to point to electrical drives being the best for a girder shop; many of the new works being put up employing them. The advantages are cleanliness, use only when required, and an entire absence of shafting. Nearly all structural tools require a fair amount of power—some taking a great deal, so that the only tools which can really be coupled together will be the drills, the separate motor system thus having a great pull. The supply of steam to separate engines on the heavy tools is not feasible, the long distances inducing so much condensation that economical work is impossible. Practically the disadvantages of the electrical drive are that it is not so economical under continuous opera-

tion—the expense per unit or horse-power being higher than for steam—so that for tools working nine hours a day it proves comparatively costly, and the upkeep is rather expensive. With heavy tools, which often work intermittently, such drawbacks are not of so much moment, since, when the motor is not going, power is not being used as it is when shafting has to be kept uselessly turning. Gas engines driving different sections are very handy, since a hitch with one does not necessarily involve the stoppage of the lot; but they take up a certain amount of space, and they do not do away with the shafting drawback, though they mitigate it to a considerable extent. Their noise and exhaust require dealing with, and if of any size they need bulky cooling apparatus; on the other hand, they are easy to drive, requiring no continuous skilled attention, and certain sections can be run overtime independently of the rest, and without the waste attendant on running a large central station for the sake of one or two tools.

With the extended application of hydraulic power to heavy tools—shears, punching presses, etc.—another method of dispensing with shafting has become open. This agent has much to recommend it, its disadvantage being the cost of installation; but for reciprocating tools, as distinct from rotary ones, such as straighteners and cold saws, it has many recommendations. The absence of complicated gearing is a distinct gain, but against this may be placed the tendency to trouble with all packings. Hydraulic punching presses are also made, but perhaps they are hardly so convenient as the lever type for ordinary work, being naturally slower in action; they are, however, unsurpassed for heavy work and for piercing. Where hydraulic riveters are being used, it is a good plan to apply the principle to a few of the tools, since once the mains are in they might as well be used to their full capacity, and there is also the advantage of not relying entirely on one agent for the work of the shop. If some of the tools—straighteners, planers, saws, and drills—are driven electrically, and others—one or two of the punchers, the shears, and the presses—driven hydraulically, it will often be possible to run sections on overtime without involving the whole, whilst a breakdown of the one will not necessarily involve the other. Hydraulic power is economical so long as there is no great leakage; when the tools are not being used, power is not running to waste; but with faulty mains or pipes it is one of the most costly.

No rules can be laid down for the positions of the driving agents in or near to the shops. Every site will be a law to itself and will have to be studied accordingly. If electricity is used a separate power station will be the best—a few yards more or less of cable making no difference. But for hydraulics, pneumatics, steam, gas, or oil, the nearer the source of power to the place of usage the better. Hydraulics and pneumatics both lose by friction and leakages, steam condenses, gas and oil waste energy turning shafting; so that according to the power decided upon will have to be the disposition of the generators. It is entirely a question for practical engineering, and to be dealt with on the spot.

The laying out of a new works, or the remodelling of an old one, is a speciality in itself. No one knows so well as the management what is really required, is frequently urged There is a vast deal of truth in this, but the other side of the case is that, whilst it will know exactly what suits its own work, yet it has not the larger view of the expert whose special business it is to keep up with the times, and who through his acquaintance with so many businesses possesses a better and safer grasp of principles. Give an expert exactly to understand what is wanted, let him make himself familiar with the details desired, and then he is much more likely to evolve a better plan than the man so wrapped up in one phase of work that he has no time to see what his neighbour is doing. The planning of a new place is not a light task; its success or failure may spell the difference between dividends and bankruptcy.

The great bugbear of modern shops is the stanchions or columns necessary between the spans. It is a bothersome thing to transfer work from one span to another, since the cranes do not lend themselves to the work at all. Attempts have been made to lessen the trouble by putting three or four spans abreast and running the work down them simultaneously into a large erecting bay at the bottom placed at right angles, but experience proves there is no gain this way. The ideal shop would undoubtedly be in one span with cranes to suit, but no one has yet been bold enough to try the experiment. The difficulty is that the capital cost seems as though it would be much more than at present. The only way to prove it is to take two schemes for the same site and work them out thoroughly, but employers do not care for such experiments. Yet in view of the gain to be effected, should the one-span idea prove feasible, it might be thought that the trial was worth making. There are shops in the States with spans of 120 ft. and even more, but Britishers still like the more moderate span. It might be that a shop with a span of 120 or 140 ft. is suited to this country, and if this were made some 300 ft. long it would turn out much more work than the one we have been discussing, whilst the erecting and machining would all be done under the one roof. Such a scheme would suit steelwork for buildings admirably, but some provision for a higher roof or part would have to be made for the erecting in a bridge workshop. It could be quite well arranged, however, by a little scheming. The girder yard with its large open space is better for working in than the shop, but its dependence on the weather has quite condemned it now. If the yard could be covered over with a roof which dispensed with columns, then would all advantages be combined, but, alas! man is but human and his tools material.

Of course the shop we have been discussing is only for a moderate-sized establishment, capable of turning out about three to seven or eight thousand tons per annum according to the class of work going through. For larger and more important places different scheming would have to be adopted. There are works in the United States having single shops larger in area than the one described and devoted to solely one thing—such as eye-bars, say! It is evident that when establishments reach this size they need radically

different arranging, and that for the sake of transporting material, etc., they must be arranged in blocks with a network of feeding railway lines, instead of being under one gigantic roof. We have no example in this country of a works possessing such an immense output of structural steelwork; our shops are of only a moderate size comparatively, and for purposes of illustration, therefore, the one described may be taken as typical of British practice.

There is a point in connection with the smithy which must not be overlooked—it must possess thorough ventilation, and all hearths should be fitted with cowls and chimneys for carrying off the sulphur, or else the sheeting of the shop will suffer to some extent. One side of the place will be open, and if good louvres are arranged in the roof a fair amount of air will find its way in.

All cranes used, of whatever type, will, of course, be driven by the power selected for the tools. If electricity and hydraulics are to be employed, all the main travellers would use the first-named, whilst the other power might be used for small cantilever cranes and for those for use with the riveters. It will entirely be a matter of expediency. For general riveting, swinging cantilevers fitted to the stanchions and small goliaths running on rails seem the handiest. It would not do to use the heavy travelling cranes for supporting hydraulic riveters, except for those parts which are too high to be reached by ordinary tackle, whilst fixed gantries are always in the way. Overhead runners are not feasible either, except when close into the sides. When plenty of power is available and space is not cramped, all smaller work can be taken to stationary riveters and handled there by suitable tackle, since clear working-room is then left in the rest of the shop. There is bound, however, to be a large part of the work to be done by portable tools, especially for the larger work, and if the shop is wide it means either using the big cranes, erecting temporary tackle, or the use of small goliaths which can be pushed anywhere by hand. The latter plan is generally adopted.

APPENDIX.

MANUFACTURERS' STANDARD SPECIFICATIONS.

(THE ACCEPTED AMERICAN STANDARD SPECIFICATIONS.)

Revised, February 1903.

STRUCTURAL STEEL.

Process of Manufacture.

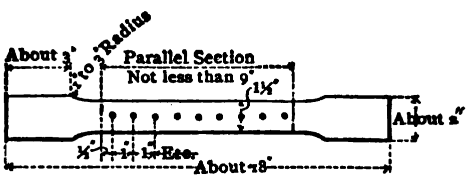
(1) Steel may be made by either the open-hearth or Bessemer process.

Testing and Inspection.

(2) All tests and inspections shall be made at the place of manufacture prior to shipment.

Test-Pieces.

(3) The tensile strength, limit of elasticity and ductility shall be determined from a standard test-piece cut from the finished material. The standard shape of the test-piece for sheared plates shall be as shown by the following sketch :—



Piece to be of same Thickness as the Plate.

On tests cut from other material, the test-piece may be either the same as for sheared plates, or it may be planed or turned parallel throughout its

AMERICAN STANDARD SPECIFICATIONS—*continued.*

entire length, and, in all cases where possible, two opposite sides of the test-piece shall be the rolled surfaces. The elongation shall be measured on an original length of 8 in., except as modified in section (12), paragraph (*c*). Rivets, rounds, and small bars shall be tested of full size as rolled.

Two test-pieces shall be taken from each melt or blow of finished material, one for tension and one for bending; but in case either test develops flaws, or the tensile test-piece breaks outside of the middle third of its gauged length, it may be discarded and another test-piece substituted therefor.

Annealed Test-Pieces.

(4) Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material shall be similarly treated before testing.

Marking.

(5) Every finished piece of steel shall be stamped with the blow or melt number, and steel for pins shall have the blow or melt number stamped on the ends. Rivet and lacing steel, and small pieces for pin-plates and stiffeners, may be shipped in bundles securely wired together, with the blow or melt number on a metal tag attached.

Finish.

(6) Finished bars shall be free from injurious seams, flaws, or cracks, and have a workmanlike finish.

CHEMICAL PROPERTIES.

(7*a*) Steel for—

Buildings, . . . Train sheds, . . Highway bridges and similar structures, .	maximum phosphorus, ·10 per cent.

(7*b*) Steel for—

Railway bridges, . .	maximum phosphorus, ·08 per cent.

AMERICAN STANDARD SPECIFICATIONS—*continued.*

PHYSICAL PROPERTIES.

(8) Structural steel shall be of three grades—RIVET, RAILWAY BRIDGE, and MEDIUM.[1]

Rivet Steel.

(9) Ultimate strength, 48,000 to 58,000 pounds per square inch.

Elastic limit, not less than one-half the ultimate strength.

Percentage of elongation, $\frac{1{,}400{,}000}{\text{ultimate strength}}$.[2]

Bending test, 180 degrees flat on itself, without fracture on outside of bent portion.

Steel for Railway Bridges.

(10) Ultimate strength, 55,000 to 65,000 pounds per square inch.[3]

Elastic limit, not less than one-half the ultimate strength.

Percentage of elongation, $\frac{1{,}400{,}000}{\text{ultimate strength}}$.[4]

Bending test, 180 degrees to a diameter equal to thickness of piece tested, without fracture on outside of bent portion.

Medium Steel.

(11) Ultimate strength, 60,000 to 70,000 pounds per square inch.

Elastic limit, not less than one-half the ultimate strength.

Percentage of elongation, $\frac{1{,}400{,}000}{\text{ultimate strength}}$.[5]

Bending test, 180 degrees to a diameter equal to thickness of piece tested, without fracture on outside of bent portion.

Modifications in Elongation for Thin and Thick Material.

(12) For material less than $\frac{5}{16}$-in. and more than $\frac{3}{4}$-in. in thickness, the following modifications shall be made in the requirements for elongation :—

[1] This used to read "RIVET, SOFT, and MEDIUM."
[2] This used to read "26 per cent."
[3] This used to read "52,000 to 62,000 pounds."
[4] This used to read "25 per cent."
[5] This used to read "22 per cent."

AMERICAN STANDARD SPECIFICATIONS—*continued.*

(*a*) For each increase of $\frac{1}{8}$-in. in thickness above $\frac{3}{4}$-in., a deduction of 1 per cent. shall be made from the specified elongation, except that the minimum elongation shall be 20 per cent. for eye-bar material and 18 per cent. for other structural material.

(*b*) For each decrease of $\frac{1}{16}$-in. in thickness below $\frac{5}{16}$-in., a deduction of $2\frac{1}{2}$ per cent. shall be made from the specified elongation.

(*c*) In rounds of $\frac{5}{8}$-in. or less in diameter, the elongation shall be measured in a length equal to eight times the diameter of section tested.

(*d*) For pins made from any of the before-mentioned grades of steel, the required elongation shall be 5 per cent. less than that specified for each grade, as determined on a test-piece, the centre of which shall be 1 in. from the surface of the bar.

Variation in Weight.

(13) The variation in cross-section or weight of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations :—

(*a*) Plates $12\frac{1}{2}$ lbs. per square foot or heavier, up to 100 in. wide, when ordered to weight, shall not average more than $2\frac{1}{2}$ per cent. variation above or $2\frac{1}{2}$ per cent. below the theoretical weight. When 100 in. wide and over, 5 per cent. above or 5 per cent. below the theoretical weight.

(*b*) Plates under $12\frac{1}{2}$ lbs. per square foot, when ordered to weight, shall not average a greater variation than the following :—

Up to 75 in. wide, $2\frac{1}{2}$ per cent. above or $2\frac{1}{2}$ per cent. below the theoretical weight; 75 in. wide up to 100 in. wide, 5 per cent. above or 3 per cent. below the theoretical weight. When 100 in. wide and over, 10 per cent. above or 3 per cent. below the theoretical weight.

(*c*) For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table :—

AMERICAN STANDARD SPECIFICATIONS—*continued.*

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over $\frac{1}{100}$-in. less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0·2833 pound.

Plates $\frac{1}{4}$-in. and over in Thickness.

Thickness of Plate.	Width of Plate.			
	Up to 75 inches.	75 to 100 inches.	Over 100 to 115 inches.	Over 115 inches.
Inch.	Per cent.	Per cent.	Per cent.	Per cent.
$\frac{1}{4}$	10	14	18	...
$\frac{5}{16}$	8	12	16	..
$\frac{3}{8}$	7	10	13	17
$\frac{7}{16}$	6	8	10	13
$\frac{1}{2}$	5	7	9	12
$\frac{9}{16}$	$4\frac{1}{2}$	$6\frac{1}{2}$	$8\frac{1}{2}$	11
$\frac{5}{8}$	4	6	8	10
Over $\frac{5}{8}$	$3\frac{1}{2}$	5	$6\frac{1}{2}$	9

Plates under $\frac{1}{4}$-in. in Thickness.

Thickness of Plate.	Width of Plate.		
	Up to 50 inches.	50 to 70 inches.	Over 70 inches.
Inch.	Per cent.	Per cent.	Per cent.
$\frac{1}{8}$ up to $\frac{5}{32}$	10	15	20
$\frac{5}{32}$ " $\frac{3}{16}$	$8\frac{1}{2}$	$12\frac{1}{2}$	17
$\frac{3}{16}$ " $\frac{1}{4}$	7	10	15

AMERICAN STANDARD SPECIFICATIONS—*continued.*

STRUCTURAL CAST-IRON.

Except when chilled iron is specified, all castings shall be tough grey iron, free from injurious cold-shuts or blow-holes, true to pattern, and of a workmanlike finish. Sample pieces, 1 in. square, cast from the same heat of metal in sand moulds, shall be capable of sustaining on a clear span of 4 ft. 8 in. a central load of 500 pounds when tested in the rough bar.

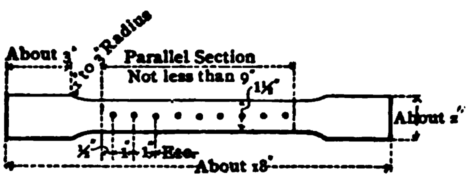
SPECIAL OPEN-HEARTH PLATE AND RIVET STEEL.

Testing and Inspection.

(1) All tests and inspections shall be made at the place of manufacture prior to shipment.

Test-Pieces.

(2) The tensile strength, limit of elasticity and ductility shall be determined from a standard test-piece cut from the finished material. The standard shape of the test-piece for sheared plates shall be as shown by the following sketch :—



Piece to be of same Thickness as the Plate.

On tests cut from other material, the test-piece may be either the same as for sheared plates, or it may be planed or turned parallel throughout its entire length, and in all cases, where possible, two opposite sides of the test-piece shall be the rolled surfaces. The elongation shall be measured on an original length of 8 in., except as modified in section (12), paragraph (*c*). Rivet rounds and small bars shall be tested of full size as rolled.

Four test-pieces shall be taken from each melt of finished material, two for

AMERICAN STANDARD SPECIFICATIONS—*continued.*

tension and two for bending; but in case either test develops flaws, or the tensile test breaks outside of the middle third of its gauged length, it may be discarded and another test-piece substituted therefor.

Annealed Test-Pieces.

(3) Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material shall be similarly treated before testing.

Marking.

(4) Every finished piece of steel shall be stamped with the melt number. Rivet steel may be shipped in bundles securely wired together, with the melt number on a metal tag attached.

Finish.

(5) All plates shall be free from injurious surface defects and have a workmanlike finish.

CHEMICAL PROPERTIES.

(6*a*) Flange or boiler steel,	maximum	phosphorus,	·06	per cent.
	,,	sulphur,	·04	,, ,,
(6*b*) Extra soft and fire-box steel,	maximum	phosphorus,	·04	per cent.
	,,	sulphur,	·04	,, ,,

PHYSICAL PROPERTIES.

(7) Special open-hearth plate and rivet steel shall be of three grades—EXTRA SOFT, FIRE-BOX, and FLANGE or BOILER STEEL.[1]

Extra Soft Steel.

(8) Ultimate strength, 45,000 to 55,000 pounds per square inch.

Elastic limit, not less than one-half the ultimate strength.

Elongation, 28 per cent.

Cold and quench bends, 180 degrees flat on itself, without fracture on outside of bent portions.

[1] This used to read "EXTRA SOFT, FIRE-BOX, FLANGE or BOILER, and BOILER RIVET STEEL" (four grades).

AMERICAN STANDARD SPECIFICATIONS—*continued.*

Fire-Box Steel.

(9) Ultimate strength, 52,000 to 62,000 pounds per square inch.

Elastic limit, not less than one half the ultimate strength.

Elongation, 26 per cent.

Cold and quench bends, 180 degrees flat on itself, without fracture on outside of bent portion.

Flange or Boiler Steel.

(10) Ultimate strength, 55,000 to 65,000 pounds per square in.[1]

Elastic limit, not less than one-half the ultimate strength.

Elongation, 25 per cent.

Cold and quench bends, 180 degrees flat on itself, without fracture on outside of bent portion.

Boiler Rivet Steel.

(11) Steel for boiler rivets shall be made of the extra soft grade specified in paragraph No. (8).

Modifications in Elongation for Thin and Thick Material.

(12) For material less than $\frac{5}{16}$-in. and more than $\frac{3}{4}$-in. in thickness, the following modifications shall be made in the requirements for elongation:—

(*a*) For each increase of $\frac{1}{8}$-in. in thickness above $\frac{3}{4}$-in., a deduction of 1 per cent. shall be made from the specified elongation.

(*b*) For each decrease of $\frac{1}{16}$-in. in thickness below $\frac{5}{16}$-in., a deduction of $2\frac{1}{2}$ per cent. shall be made from the specified elongation.

(*c*) In rounds of $\frac{5}{8}$-in. or less in diameter, the elongation shall be measured in a length equal to eight times the diameter of section tested.

Variation in Weight.

(13) The variation in cross-section or weight of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:—

(*a*) Plates $12\frac{1}{2}$ pounds per square foot or heavier, up to 100 in. wide when ordered to weight, shall not average more than $2\frac{1}{2}$ per cent. variation above or $2\frac{1}{2}$ per cent. below the theoretical weight. When 100 in. wide and over, 5 per cent. above or 5 per cent. below the theoretical weight.

[1] This used to read "52,000 to 62,000 pounds per square inch."

AMERICAN STANDARD SPECIFICATIONS—*continued.*

(*b*) Plates under 12½ pounds per square foot, when ordered to weight, shall not average a greater variation than the following :—

Up to 75 in. wide, 2½ per cent. above or 2½ per cent. below the theoretical weight. 75 in. wide up to 100 in. wide, 5 per cent. above or 3 per cent. below the theoretical weight. When 100 in. wide and over, 10 per cent. above or 3 per cent. below the theoretical weight.

(*c*) For all plates ordered to gauge there will be permitted an average excess of weight over that corresponding to the dimensions or the order equal in amount to that specified in the following table :—

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over $\frac{1}{100}$-in. less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0·2833 pound.

Plates $\frac{1}{4}$*-in. and over in Thickness.*

THICKNESS OF PLATE.	WIDTH OF PLATE.			
	Up to 75 inches.	75 to 100 inches.	Over 100 to 115 inches.	Over 115 inches
Inch.	Per cent.	Per cent.	Per cent.	Per cent.
$\frac{1}{4}$	10	14	18	...
$\frac{5}{16}$	8	12	16	...
$\frac{3}{8}$	7	10	13	17
$\frac{7}{16}$	6	8	10	13
$\frac{1}{2}$	5	7	9	12
$\frac{9}{16}$	4½	6½	8½	11
$\frac{5}{8}$	4	6	8	10
Over $\frac{5}{8}$	3½	5	6½	9

AMERICAN STANDARD SPECIFICATIONS—*continued.*

Plates under $\frac{1}{4}$-in. in Thickness.

Thickness of Plate.	Width of Plate.		
	Up to 50 inches.	50 to 70 inches.	Over 70 inches.
Inch.	Per cent.	Per cent.	Per cent.
$\frac{1}{8}$ up to $\frac{5}{32}$	10	15	20
$\frac{5}{32}$ " $\frac{3}{16}$	$8\frac{1}{2}$	$12\frac{1}{2}$	17
$\frac{3}{16}$ " $\frac{1}{4}$	7	10	15

SPECIFICATION FOR WORKMANSHIP.

Inspection.

(1) Inspection of work shall be made as it progresses, and at as early a period as the nature of the work permits.

(2) All workmanship must be first-class. All abutting surfaces of compression members, except flanges of plate girders where the joints are fully spliced, must be planed or turned to even bearings, so that they shall be in such contact throughout as may be obtained by such means. All finished surfaces must be protected by white lead and tallow.

(3) The rivet-holes for splice plates of abutting members shall be so accurately spaced that when the members are brought into position the holes shall be truly opposite before the rivets are driven.

(4) Rollers must be finished perfectly round, and roller beds planed.

Rivets.

(5) The pitch of rivets in all classes of work shall never exceed 6 in., nor sixteen times the thinnest outside plate, nor be less than three diameters of the rivet. The rivets used shall generally be $\frac{5}{8}$, $\frac{3}{4}$, and $\frac{7}{8}$-in. diameter. The distance between the edge of any piece and the centre of a rivet-hole must

AMERICAN STANDARD SPECIFICATIONS—*continued.*

never be less than $1\frac{1}{4}$ in., except for bars less than $2\frac{1}{2}$ in. wide. When practicable it shall be at least two diameters of the rivet. Rivets must completely fill the holes, have full head concentric with the rivet, of a height not less than ·6 the diameter of the rivet, and in full contact with the surface, or be countersunk when so required, and machine-driven wherever practicable.

Punching.

(6) The diameter of the punch shall not exceed by more than $\frac{1}{16}$ in. the diameter of the rivets to be used, and all holes must be clean cuts without torn or ragged edges. Rivet-holes must be accurately spaced; the use of drift pins will be allowed only for bringing together the several parts forming a member, and they must not be driven with such force as to disturb the metal about the holes.

(7) Built members must, when finished, be true and free from twists, kinks, buckles, or open joints between the component pieces.

Eye-bars and Pin-holes.

(8) All pin-holes must be accurately bored at right angles to the axis of the members, unless otherwise shown in the drawings, and in pieces not adjustable for length no variation of more than $\frac{1}{32}$ of an inch will be allowed in the length between centres of pin-holes; the diameter of the pin-holes shall not exceed that of the pins by more than $\frac{1}{32}$ in., nor by more than $\frac{1}{50}$ in. for pins under $3\frac{1}{2}$ in. diameter. Eye-bars must be straight before boring; the holes must be in the centre of the heads and on the centre line of the bars. Wherever eye-bars are to be packed more than $\frac{1}{8}$ of an inch to the foot of their length out of parallel with the axis of the structure, they must be bent with a gentle curve until the head stands at right angles to the pin in their intended positions before being bored. All eye-bars belonging to the same panel, when placed in a pile, must allow the pin at each end to pass through at the same time without forcing. No welds will be allowed in the body of the bar of eye-bars, laterals, or counters, except to form the loops of laterals, counters, and sway rods; eyes of laterals, stirrups, sway rods, and counters must be bored; pins and lateral bolts must be finished perfectly round and straight; and the party contracting to erect the work must provide pilot-nuts where necessary to preserve the threads while the pins are being driven. Thimbles or washers must be used whenever required to fill the vacant spaces on pins or bolts.

AMERICAN STANDARD SPECIFICATIONS—*continued.*

Annealing.

(9) In all cases where a steel piece in which the full strength is required has been partially heated, the whole piece must be subsequently annealed. All bends in steel must be made cold; or if the degree of curvature is so great as to require heating, the whole piece must be subsequently annealed.

Painting.

(10) All surfaces inaccessible after assembling must be well painted or oiled before the parts are assembled.

(11) The decision of the engineer shall control as to the interpretation of drawings and specifications during the execution of work thereunder; but this shall not deprive the contractor of his right to redress, after the completion of the work, for an improper decision.

A SPECIFICATION FOR BRITISH STEELWORK.[1]

(1) *Materials.*—The steel to be used in this work may be made by either the basic or Siemens open-hearth processes.

(2) *Quality and Tests.*—The steel for plates, joists, and all sectional material shall be of such a quality that test-strips cut from the bulk shall show a tensional strength of 28 to 32 tons per square inch of original area, together with an elongation of at least 20 per cent. in 8 in., and a contraction of area equal to 40 per cent. at the point of fracture.

The steel for rivets shall have a tensional strength of not less than 24 tons per square inch of original area, and show an elongation of not less than 25 per cent. measured on a length of at least eight times the diameter being tested. Where possible, rivet rounds shall be tested of the full size as rolled.

(3) *Elastic Limit.*—The elastic limit shall in all cases be not less than one-half the ultimate strength.

(4) *Bending Tests.*—Strips cut from plates and sectional materials shall bend cold through 180 degrees, with a radius on the inner side of the bend of one-half the thickness being tested, without showing signs of fracture in any part. All rivet steel shall, when cold, bend through 180 degrees flat upon itself without any sign of fracture.

(5) *Test-Pieces.*—All the steel from every cast shall be plainly stamped with the cast number or identifying mark, and from each cast at least two test-pieces shall be taken, which shall be stamped with corresponding marks. Should the test-pieces fail to stand the prescribed tests, and there be no visible flaws present, all the material from those particular casts shall be at once rejected and be replaced by other and better material.

(6) *Finish.*—All plates, bars, joists, and sectional material shall be well and cleanly rolled and free from scales, blisters, laminations, cracked edges, or

[1] This is a suggested model specification for the guidance of engineers and designers generally in drafting specifications for their own work. As mentioned in the text, it is drafted so as to cover all reasonable requirements, and to thoroughly safeguard the buyer, and, at the same time, is not too onerous for the manufacturer to undertake at bottom prices. From an intimate acquaintance with both the design and manufacture of steelwork for all purposes, the author is able to give his assurance that it is a perfectly fair document for both designer and maker, and equally safeguards both.

A SPECIFICATION FOR BRITISH STEELWORK—*continued.*

other defects. They shall be of exact dimensions, holding fully up to those marked on the drawings, and be perfectly rolled in every way.

(7) ***Inspection of Testing, etc.***—The engineer, or his accredited representative, shall superintend the breaking of the test-strips at the rolling mills, personally assuring himself of the correctness of all results. If he so desires, he shall be at liberty to witness the operation of rolling, or any other operation incident to the production of the material. When satisfied that the material conforms to this specification, he shall stamp each piece with his own private stamp, and no material shall be allowed to leave the mills without bearing such stamp.

(8) ***Independent Tests.***[1]—The engineer reserves the right to select further test-strips from the bulk, which may be sent to any recognised public testing-house, there to be prepared and tested at his expense, as a further check and evidence of quality. Should such strips when tested fail to agree with the results of the tests conducted at the rolling mills, further strips shall be selected and sent to another public testing-house, when, if the quality is again proved below standard, the engineer shall have the power to refuse to accept the parcels of materials from which they were cut. Pending the results of such tests, the material shall not leave the mills. In all cases the receipt by the mills of the engineer's order to despatch materials shall be conclusive evidence of his satisfaction and agreement with its quality.

(9) ***Engineer's Sanction.***—All work is to be made in strict accordance with the drawings and this specification, and no departures therefrom are to be made in any particular without the written sanction of the engineer being first obtained.

(10) ***Rivet-Holes.***[2]—All rivet-holes must be accurately set out to template, and be of the exact pitch and position as figured on the drawings. They may be first nipple-punched $\frac{1}{4}$ in. less in diameter than the finished

[1] Only to be inserted in the case of very heavy and important work. Such a clause (not being an absolutely necessary one) does but increase costs without giving corresponding advantages.

[2] If punched work is desired, this clause should read :—All rivet-holes must be accurately set out to template and be of the exact pitch and position as figured on the drawings. They shall be nipple-punched, and the punch used shall not exceed the diameter of the rivets to be used by more than $\frac{1}{16}$ in. In all cases they shall be perfectly fair and true throughout, and when assembled the holes shall be so true that the rivets to be used will pass easily through the several assembled thicknesses.

hole, and when assembled reamed out to full size, or drilled from the solid, at the maker's option. In all cases they shall be perfectly fair and true throughout, and of the figured diameters on the drawings.

(11) ***Rivets.***—Rivets shall be clean, with full-sized, well-formed heads, each head containing not less material than a length equal to one and a half times the diameter of its shank. They shall completely fill their holes, and shall be of such a diameter that when cold, and previous to driving, they will fill their holes without perceptible shake. No cracked, burnt, badly formed, or other defective heads will be allowed.

(12) ***Smithwork, etc.***—All smithwork shall be clean and sound, and the metal shall not be burnt or injured in any way. All bends, wherever possible, must be made cold; and should it be necessary to use heat for members which will be subjected to direct stress in the finished work, they shall be subsequently annealed in every case, excepting girder stiffeners.

(13) ***Workmanship generally.***—The workmanship throughout shall be sound, honest, and clean. All abutting ends of plates and bars shall be planed and truly meet, all joints be perfectly fair, all members true and not in winding when built, all bearing surfaces level, rivets countersunk where required, and generally a thoroughly good job made.

(14) ***Painting, etc.***—Before assembling, all frazes shall be carefully removed from the rivet-holes, and all surfaces in contact and inaccessible when built shall be well cleaned and have a coat of boiled oil. After assembling, the members shall be well scraped and cleaned and be given one coat of best oil paint.

Note.—The foregoing are all the clauses necessary so far as the steelwork is concerned. Special clauses descriptive of the work or conditions necessary to its execution owing to difficulties of site, a time clause, and other germane matters might then usefully follow. It should, however, always be borne in mind that any conditions should be made as little onerous as possible, and that all limitations imposed should be absolutely necessary ones. The fewer the clauses and the easier the restrictions of a specification, the keener the price at which it can be done is a correlation that should never be lost sight of. When the time comes that an engineer can simply say, "The work to be carried out in strict conformity to the specification" (naming a recognised standard), we shall have far better and cheaper work, and time deliveries will be cut in half.

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